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RELATION BETWEEN CIRRUS DIRECTIONS AS OBSERVED IN MELBOURNE AND THE APPROACH OF THE VARIOUS STORM SYSTEMS AFFECTING VICTORIA

BY

E. T. QUAYLE, B.A.,

ASSISTANT, COMMONWEALTH METEOROLOGICAL BUREAU, MELBOURNE.

BULLETIN No. 10.

(ISSUED MAY, 1915.)

Published with the Authority of the Minister for Home Affairs.

H. A. HUNT

COMMONWEALTH METEOROLOGIST.

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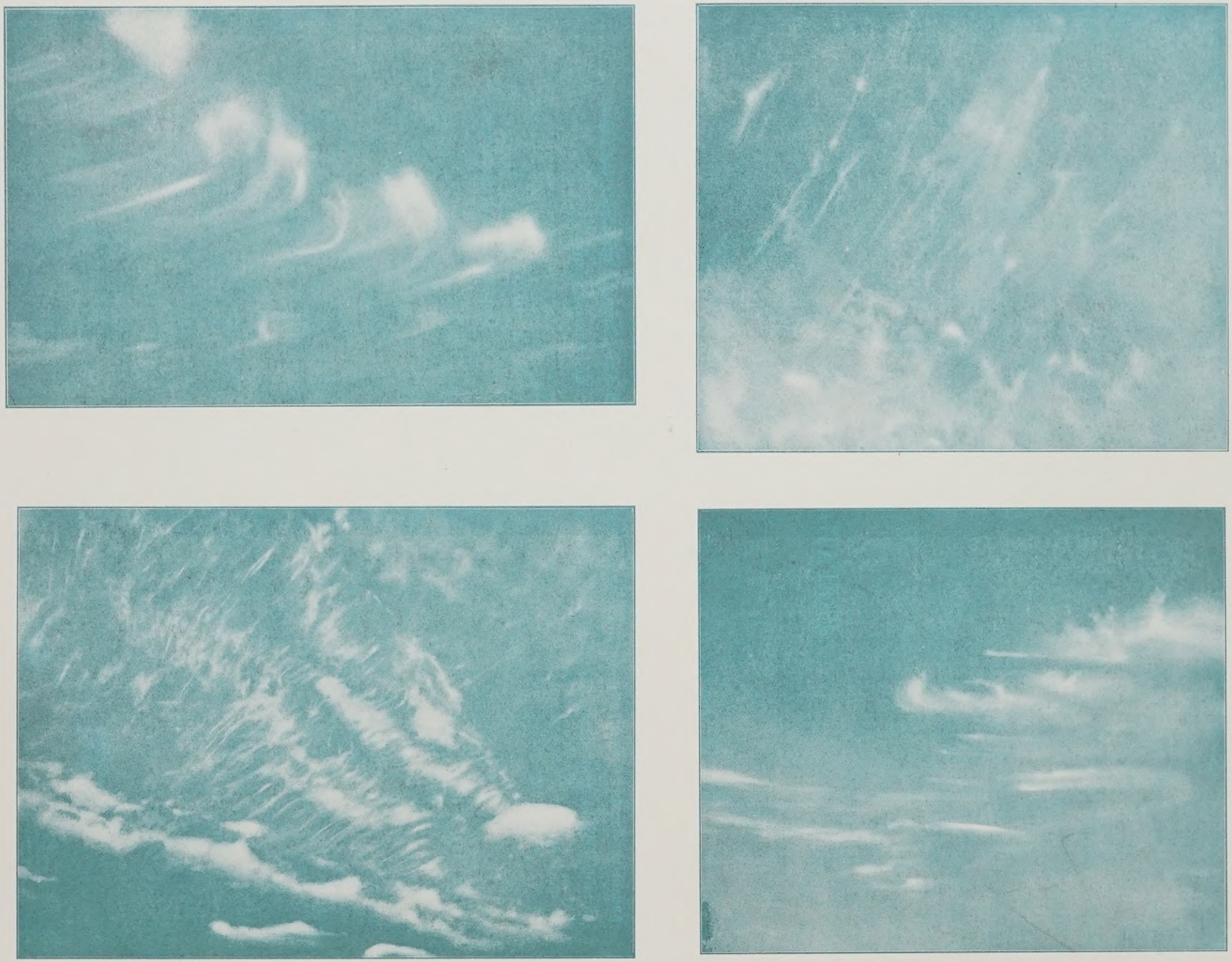
TYPES OF CIRRUS.



[*From the International Cloud Atlas.*]

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PREFATORY NOTE.

The deductions which Mr. Quayle has arrived at in the discussion of his observations of cloud movements in Melbourne, extending over a great number of years, form a distinct advance in Australian meteorological knowledge. This work will be of considerable assistance in framing and increasing the accuracy of our forecasts, and in the hands of country residents will enable them to gauge with some degree of probability the amount of rain likely to result during the passage of depressions of the various types described.

H. A. HUNT,
Commonwealth Meteorologist.

12th May, 1915.

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INTRODUCTION.

As guides for the local forecaster, it may safely be said that there are no weather indications comparable in importance with those obtainable from systematic study of cloud forms, and of these, Cirrus types are easily first. It is to the direction of movement of these cloud forms that attention is to be confined in the following series of papers, and it is sincerely hoped that they may be of some use in stimulating meteorologists, whether professional or amateur, in different parts of this great continent to initiate a regular and systematic record of the behaviour of the various cloud types observable. While none should be neglected, there is no doubt that special attention should be given to the movements of Cirrus clouds since these are our only cloud indication of the translation of air masses at high level, the direction of which appears to have a most important bearing upon storm developments at lower levels.

The following may serve to illustrate this :—

It not infrequently happens, in the summer half of the year chiefly, that monsoonal conditions prevailing over Victoria are accompanied by quiet hot weather, extensive thunderstorm developments, and in parts heavy rains, the clouds meanwhile from Cumulus base level to the higher Cirrus wisps moving slowly from some Northerly point. If now Cirrus clouds are observed in the Western or South-western horizon coming up from a point between West and South, or the loftier Cumulus summits appear to be caught in an upper current coming from such a direction, the end of the thunderstorm production is close at hand. The Westerly upper current in this case would generally be the first indication of an "Antarctic" disturbance centred perhaps 1,000 to 2,000 miles away.

Again, there is one type of storm, the development and approach of which are extremely well indicated by Cirrus movements—that of a tropical disturbance moving Southwards from the interior of Queensland. When the barometer is very high owing to an intense anticyclone moving Eastward along the South coast-line, it occasionally happens that Cirrus begins to stream Southwards over Melbourne from points between North-west and N.N.E. This is an almost infallible indication of widespread rains having set in or being about to set in over Southern Queensland and inland New South Wales, and a very good indication of general rains over Northern Victoria in the near future. Many other illustrations of the value of these observations might be given, a fact which, it is hoped, may be evident in the following discussion.

The value of systematic Cirrus observations in obtaining useful indications of the probable rain production of approaching storm systems will always be found to be considerable, but especially over inland areas, which obtain their rains almost solely from definite storm systems. Near the coast the uplift given by the land to the lowest and moisture-laden air stratum coming off the sea is of itself often sufficient to cause considerable amount of rain, even under obviously anti-cyclonic conditions.

It may be added here that the great altitude at which the Cirrus clouds float corresponds with a more uniform drift and less dependence upon the surface isobars than is shown by clouds of lower levels to such an extent that observations made over the rest of Victoria usually do not give results differing materially from those made in Melbourne.

In connexion with the following, a previous paper, "On the Seasonal and Annual Variations in the Drift of Cirrus Cloud over Melbourne," published in the Monthly Meteorological Report, December, 1910, gives some useful information, and should be read. This, moreover, indicates a wider scope for observations of Cirrus movement, as it suggests the possibility of even making seasonal forecasts from them.

RELATION BETWEEN CIRRUS DIRECTIONS, AS OBSERVED IN MELBOURNE, AND THE APPROACH OF THE CHIEF TYPES OF STORM SYSTEM AFFECTING VICTORIA.

The primary purpose in the following discussion is to show the relation between Cirrus movements, as determined by observations made in Melbourne, and the approach of the various types of storm systems affecting the weather of Victoria. This relation will be shown to be twofold—that is, that not only do cyclonic systems of air circulation usually extend their influence to Cirrus level, but that the general drift of the air at that level has an influence in determining the development and translation of cyclonic or other storm systems. This has involved the preparation of complete lists of the various storm types and these may usefully be discussed from other points of view, such as frequency of occurrence, tracks, rain production, &c. The various storm types affecting Victoria may be classified as follows :—

Type I.—Antarctic V-Depressions.

Type II.—Antarctic Cyclones passing through Bass Strait.

Type III.—Antarctic Cyclones passing over Victoria or Southern New South Wales.

Type IV.—Antarctic Cyclones passing inland from the Bight North-eastwards.

Type V.—Cyclonic Depressions originating in or crossing the Western interior of the Continent, and passing South of Melbourne.

Type VIa.—Cyclonic Depressions originating in or crossing the Western interior of the Continent, and passing North of Melbourne.

Type VIb.—Cyclonic Depressions originating in or crossing the Western interior of the Continent, and moving North of East from South Australia.

Type VII.—Tropical Depressions originating over Queensland and pressing Southwards.

Type VIII.—Cyclones off the Coast of New South Wales.

THE RELATION BETWEEN CIRRUS DIRECTION AND "ANTARCTIC" V-DEPRESSIONS.

Type I.

Storms of this type form the bulk of the low pressure systems affecting Victoria and the South coastal areas of Australia generally. In most cases these are probably cyclonic; that is, in connexion with each there is some area of lowest pressure which may be regarded as the controlling centre of the wind circulation, but too far South to be definitely located. In a moderate percentage of cases, the storm centre is first indicated somewhere off the West coast of Western Australia, whence it rounds Cape Leeuwin, and thereafter proceeds Eastwards as an ordinary "Antarctic." A few such actually cross Western Australia as definite cyclonic depressions, and reach Southern waters a little West from the head of the Bight. These are all very evidently of oversea tropical origin, and are probably simply observable instances of the origin of at least some of the great "Antarctic" disturbances drifting Eastwards in Southern latitudes above 35° or 40°.

For the purpose of this paper, no distinction depending upon origin has been made; all V-depressions are regarded as "Antarctic" whose centres pass South of Bass Strait.

The influence of these disturbances upon cloud circulation at any one place will, of course, depend upon several factors, such as the distance of the storm centre to westward, the location of the storm track, the strength of the storm itself, the general direction of drift of the upper air, the age of the storm, &c., &c.

The cloud observations upon which the following results and conclusions are based are those made from the beginning of 1895 to the end of 1912. Not all storms, but only a rather small percentage of the total number, have provided usable material. In very many cases the position of the trough has been too uncertain, one storm possibly interfering with another, or Cirrus has not been observed or observable owing to the prevalence of lower clouds, or the storm has failed to produce Cirrus, &c.

The total number of Antarctic V-disturbances studied with reference to their Cirrus production is 148, distributed throughout the year as follows :—January, 10; February, 7; March, 7; April, 13; May, 16; June, 12; July, 12; August, 18; September, 16; October, 16; November, 11; December, 10.

The Cirrus observations in connexion with each approaching storm trough were dealt with in the following way. For each cloud observation used, or Cirrus direction observed, was given the distance of the trough, the departure from the mean cloud direction for this distance, the daily rate of motion of the trough, the time of passage of the trough over Melbourne, and the storm intensity in Victoria as shown by the lowest barometer reading on the isobaric chart, and the character of the rainfall over Victoria as the result of the storm.

To relate the first two, a table was prepared showing the mean Cirrus direction over Melbourne for the various distances of the storm trough. This varied from month to month in a most interesting fashion. As in every case the Cirrus movement was from some westerly point, it was convenient to call true West zero and use the + sign for Northerly deviations and the — sign for Southerly deviations from West, these being given in degrees. The most Northerly average Cirrus direction for any trough distance is in August, when it is slightly North of West for storms the trough distance of which is 1,000 miles, and the least Northerly in January and November, when it is Southerly for any distance greater than 500 miles. There would appear to be a slight increase in the tendency for Cirrus direction to deviate Northerly in March and April, which may be due to monsoonal overflows during these months. The table has been obtained by grouping observations according to trough distances in miles, 0–200, 201–400, &c., for each month, and by the use of squared paper plotting these so that curves could be drawn showing trough distances from month to month for every 10° variation in Cirrus direction. It contains some anomalies, which are inevitable in so limited a number of observations, but brings out unmistakably the existence of marked differences between the winter and summer general drift of the upper air, the winter drift being from the more Northerly points. Some of the difference is evidently due to the tracks of the lows being further South in summer than in winter.

TABLE I.

Mean Cirrus Directions as observed in Melbourne for Trough Distances of ordinary "Antarctic" V's.

Month.	Trough Distance in Miles.													
	1400	1300	1200	1100	1000	900	800	700	600	500	400	300	200	100
	Deviation in degrees from due West, + = North.													
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January ..	..	..	..	..	..	−18	−15	−13	− 7	− 2	+ 7	+16	+26	+37
February ..	..	..	..	..	..	−17	−14	− 8	− 3	+ 8	+17	+25	+31	+38
March ..	..	..	..	..	−17	−14	− 9	− 3	+ 8	+17	+23	+27	+32	+37
April ..	..	..	−28	−21	−16	−11	− 3	+ 5	+13	+18	+23	+26	+31	+35
May ..	..	−28	−22	−16	−14	− 8	+ 1	+ 6	+12	+15	+20	+25	+28	+33
June ..	..	−18	−16	−14	−10	− 6	− 4	+ 3	+13	+17	+23	+27	+32	+36
July ..	..	−13	− 8	− 5	− 3	− 1	+ 4	+ 7	+14	+21	+26	+32	+35	+38
August ..	..	−13	− 7	− 3	+ 1	+ 4	+ 6	+10	+16	+23	+27	+33	+36	+41
September ..	..	..	−18	−13	− 7	− 4	+ 2	+ 6	+14	+22	+26	+31	+34	+42
October ..	..	..	..	−22	−15	− 8	− 1	+ 5	+12	+16	+23	+26	+32	+37
November ..	..	..	..	..	−24	−16	− 7	0	+ 5	+11	+15	+19	+25	+32
December ..	..	..	..	..	−27	−24	−17	−12	− 6	− 3	+ 4	+ 7	+17	+31
Year ..	..	..	..	..	−14	−10	− 5	+ 0	+ 8	+14	+20	+25	+30	+36

The results are of sufficient interest to represent graphically. If we take the distance of the trough as the ordinate, and the time of the year as the abscissa, the curves drawn will represent the means of the Cirrus directions observed.

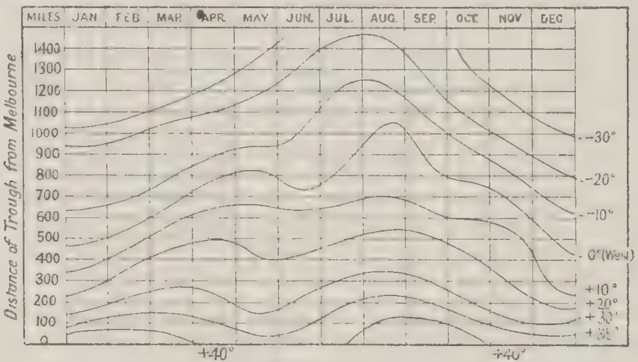


Figure I.

TABLE II.

For First Cirrus Observations.

From the following table it would seem that the scope of influence of summer "Antarctic V's" is less than that of winter storms, but the rate of movement more rapid.

Month.	Mean Cirrus Direction.	Mean Distance of Trough.	Daily Rate of Trough Movement.
		miles.	miles.
January	−11	679	680
February	−15	744	811
March	− 9	922	860
April	−19	1,065	674
May	−19	1,204	718
June	−21	1,194	554
July	− 9	1,201	487
August	− 6	1,031	623
September	−22	1,028	549
October	− 9	835	719
November	−28	967	713
December	−29	892	872

The increased rate of movement in summer might be explained by the assumption that the storm centres lie further south during this season, in the very rapidly-moving atmospheric drift of the "roaring forties." It is certainly an almost invariable rule that storms distinctly cyclonic and centred near our South coast-line move much more slowly than the average storm. This will, however, become more apparent later.

CIRRUS DIRECTION AND RAIN FORECASTING.

In order to indicate in some systematic manner the value of Cirrus observations of direction in gauging the probabilities of rain resulting from the approaching storm. Table I. was used to give a mean relation between the trough distance and Cirrus direction. For the sake of something definite, the yearly average was used. This was preferred to a seasonal one, owing to the annual variation in the latitudes of the storm track, and the obvious fact that a much larger percentage of winter than of summer Antarctic storms bring rain, the relation between these two being evidently direct.

The storms were now grouped according to the rain resulting from them. Of these 25 gave practically no rain, 46 gave partial rains ("partial" being taken to mean limited to the highlands and southern parts of the State), and 74 gave general rains. The following results were obtained :—

Rain Results.	Departure from Normal Cirrus Direction for Trough Distance.	Corresponding Mean Trough Distance.	Mean Daily Trough Rate.	Mean Minimum Barometer Reading.
		miles.	miles.	
Rain failure ..	−12°	738	828	29·78
Rains, partial	− 4°	786	741	29·74
Rains, general	+ 8°	760	607	29·69

Three facts stand out very prominently here :—First, the 20° difference between the mean Cirrus direction for rain-bearing and non-rain-bearing storms ; second, the slower movement of rain storms ; and, third, the comparatively slight difference between the barometer readings. That these are not entirely due to the greater frequency of general rain in winter may be seen by taking out the same data for the wetter months only (April to October inclusive), for which the following result is obtained :—

Rain Results.	Departure from Normal Cirrus Direction for Trough Distance.	Trough Rate.	Mean Minimum Barometer.
Rain failure	− 3½°	812	29·89
Rains, partial	− 1°	733	29·78
Rains, general	+10°	577	29·70

The number of rain failures (six) during these months was, however, insufficient for any reliable determination. Of the others, partial rains numbered 32, and general rains 62.

The forecast value, if any, of Cirrus observations of direction will evidently lie in some correspondence between the rainfall resulting from the storm, and the more or less systematic departures of Cirrus movements from the normal direction for lessening trough distances. Adopting the method previously used to obtain normal direction values for varying trough distances, the following results were obtained :—

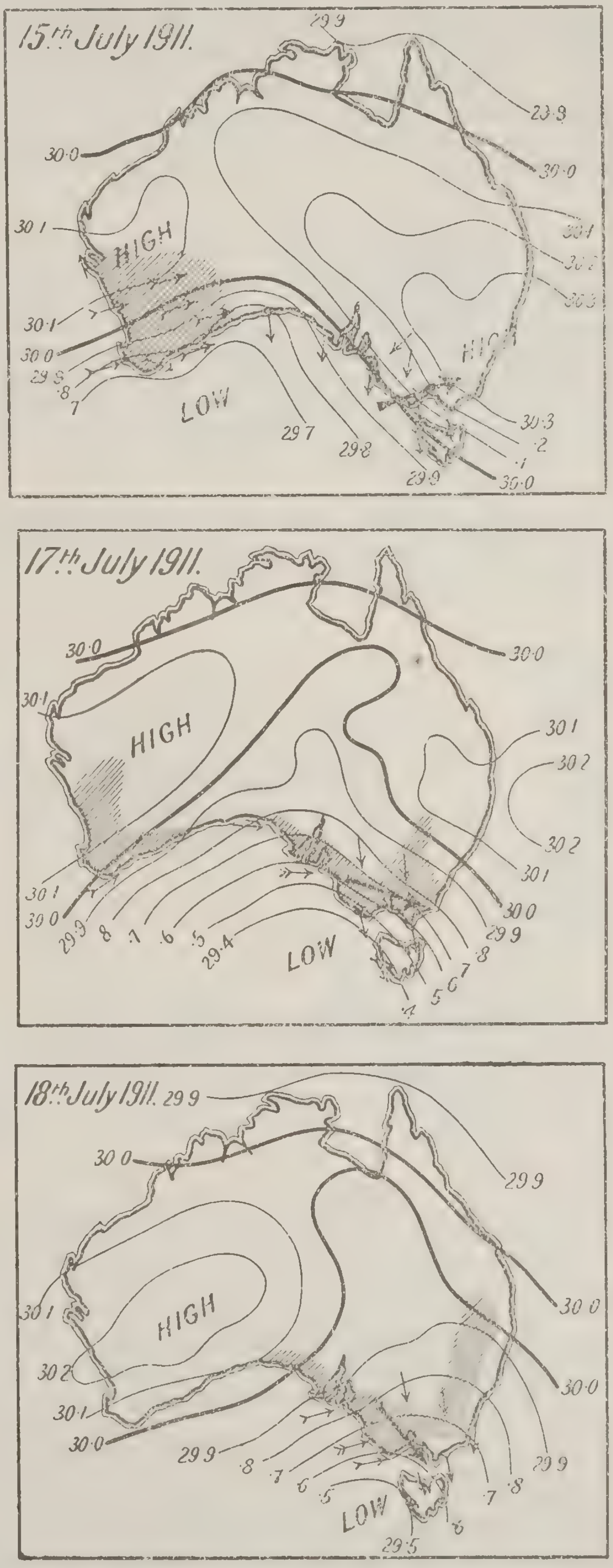
Rain Failure.			Partial Rain.			General Rain.		
Trough Distance.	Cirrus Direction.	No. of Observations.	Trough Distance.	Cirrus Direction.	No. of Observations.	Trough Distance.	Cirrus Direction.	No. of Observations.
miles.			miles.			miles.		
1,215	—29	15	1,325	—32	22	1,239	—12½	47
922	—14	9	893	—10	20	910	— 3	27
702	— 5	9	703	— 2½	15	691	+ 9½	39
528	(+ 6)	(3)	509	+13	14	520	+ 22	24
304	+ 2	7	260	(+ 3)	(2)	298	+ 30	17
63	+17	7	70	+30	10	81	+ 45	18

For the sake of demonstrating the difference more clearly, the results may be put, by the aid of a little interpolation, in the following form :—

Trough Distance.	Mean Cirrus Direction.		
	Rain Failure.	Rains, Partial.	Rains, General.
miles.	°	°	°
1,400	— 38	— 36	— 19
1,300	— 33	— 30	— 15
1,200	— 28	— 24	— 12
1,100	— 23	— 19	— 9
1,000	— 18	— 13	— 5
900	— 13	— 8	— 0
800	— 9	— 3	+ 5
700	— 5	+ 2	+ 10
600	— 2	+ 7	+ 15
500	+ 1	+ 12	+ 20
400	+ 4	+ 16	+ 25
300	+ 7	+ 20	+ 30
200	+ 11	+ 25	+ 36
100	+ 15	+ 29	+ 43

These are results which, to some extent, might have been anticipated, inasmuch as rain would be most probable from storms the tracks for the centres of which tended to work more Northerly, and so approach the observer, and least probable from those which tended to slip Southwards, and the Cirrus movements would tend to correspond with these.

Below are shown partial copies of weather charts illustrating an ordinary Antarctic V-depression. The small arrows denote wind directions, the bolder arrows the Cirrus directions over Melbourne as actually observed, and the shading the areas over which rain was recorded during the previous 24 hours.



Small arrows indicate wind directions ; bold arrows, the Cirrus direction over Melbourne ; shaded areas, the rainfall distribution during the preceding 24 hours.

TYPE II.—ANTARCTIC CYCLONES PASSING THROUGH BASS STRAIT.

This type of storm is assumed to belong to the same class as that of the V-depression just dealt with, being simply a particular case in which a centre of energy as shown by the lowest barometer readings is formed far enough North to pass through Bass Strait. The results obtained in this study tend to show, however, that, although no reports have, at all events until lately, been obtainable from the ocean to the southward of Australia, these storms are usually definitely cyclonic for some considerable time before their eastward progress through Bass Strait makes this evident. From the ordinary Antarctic they differ in their manifestations greatly in several ways, as will be seen hereafter.

One interesting feature of these storms is that in almost every case they give Cirrus indications for several days in advance of the passage of their centres. The total number of storms passing through Bass Strait during the years 1895 to 1913 inclusive is 62, and in 53 cases Cirrus was observable in advance of the centre. This is very much more than in the case of ordinary Antarctics, the total number of which for the same period was 875, and those giving Cirrus indications probably not more than half that number.

The probability of their occurrence is greatest in July, for which the total for eighteen years is 13, and lowest in February, when only 1 occurred. The storm totals during the period for each month are as follows :—

January ..	4
February ..	1
March ..	3
April	5
May	7
June	7
July	13
August ..	8
September ..	7
October ..	3
November ..	2
December ..	2

These give a seasonal curve, differing decidedly from that of the "Antarctics" which reach their maximum during October.

A most interesting and important point in connexion with these storms is the general and heavy rainfall which practically always takes place over Victoria as they pass through Bass Strait. In no less than 57 cases the rain was quite general, and in parts heavy, and in the remaining 5 there was only partial failure.

But, though they practically never fail to bring widespread and even heavy rains, their frequency in any one year does not seem to have any special effect upon the annual rainfall totals, as their average number during the dryer years is only slightly less than that in wet. This seems to suggest that their formation is independent of the intensity, frequency, or latitudinal variation of the "Antarctic" disturbances which give the bulk of the winter rainfall of the Southern portion of the continent.

The yearly numbers range from *nil* in 1906 and 1912 to 9 in 1905.

The Cirrus directions, as seen over Melbourne and the corresponding distances of storm centres, have been taken out in the same way as was previously done with regard to Antarctic troughs. The storm centre, as it approaches, is probably nearly always about due West. The following table gives the average results :—

Distance in Miles.	Cirrus Direction.	Number of Observations.
	°	
1,010	+ 7	19
711	+ 47	15
504	+ 30	22
313	+ 44	24
102	+ 47	15

The mean daily rate of approach for these storms is 410 miles. Three gave rates of less than 200 miles per day, and fifteen between 200 and 300 miles daily. This is much less than that for any other class of Antarctic disturbance.

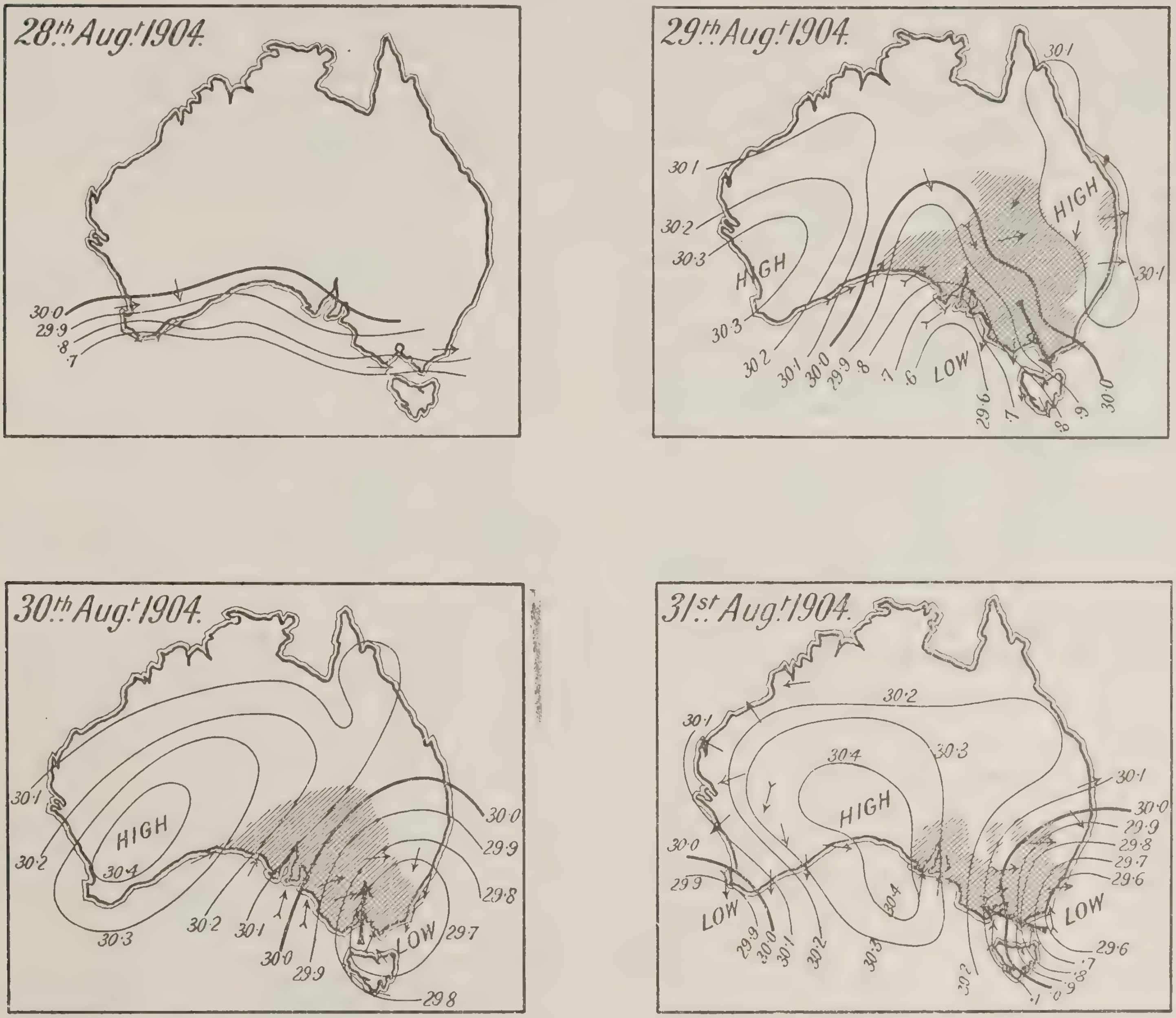
The above table does not show the same steady progressions in the backing of Cirrus directions as is noticeable in the case of the ordinary Antarctic V-depression. The only violent departure from a fairly regular progressive variation is, however, at the 711 mile distance, which is only partly due to the fact that all but two of the 22 observations made at the next distance—504 miles—were for different storms. Then at the shortest distance —102 miles—the direction of movement is not so Northerly as one would expect.

These peculiarities may be partly explained as follows. Dealing first with the latter, there is occasional conflict of testimony between the indications obtained at sea-level and those given by the movements of the high-level clouds with regard to the position of the storm centre, the clouds at Cirrus level moving as if the centre were passing, while the low-level clouds and the lowest barometric readings declare it to be still a little to Westward. This is most liable to happen in the case of ill-defined storms with slight gradients in which case the Cirrus clouds will be seen for some time before the barometric centre passes, moving very slowly and irregularly, at times from points South of West. There is some reason for thinking that this may be due to the land masses bounding the Strait making conditions less favorable for cyclonic development within the Strait than off the Western and Eastern entrances. The weather charts would, therefore, make it appear that the barometric centre tended to pass rather suddenly from the Western to the Eastern end of the Strait.

The very Northerly tendency of Cirrus directions over Melbourne during the advance of an "Antarctic" cyclone from the Westward, especially when the storm centre is over 500 miles away, is too greatly different from those usually observed with the ordinary V-depression for the assumption to be valid that control is of similar type in both cases. It seems to point rather to the probability that a decidedly poleward drift at upper levels of the atmosphere is highly favorable for cyclonic developments, and that many of the cyclones apparently originating in Antarctic low pressure systems are really due to an extensive Southward drift of the air at upper, including Cirrus, levels. Evidence of a similar character will be adduced in other connexions later.

The maps printed below give an actual illustration of this type of storm.

Type II.—Antarctic Cyclone passing through Bass Strait.



Small arrows indicate wind directions; bold arrows the Cirrus directions over Melbourne; shaded areas the rainfall distribution during the preceding 24 hours.

Type III.—Antarctic Cyclones Passing Inland over Victoria and Southern New South Wales.

This type of storm probably does not differ essentially from the preceding in its origin, but owing to its taking an inland track the weather, cloud control over Melbourne, and rates of motion show some very marked differences. No matter how feebly outlined barometrically they are always attended by widespread inland rains, usually heavy and extending to at least three States, namely, South Australia, Victoria, and New South Wales. Their cloud control is nearly always complete, that is, even the Cirrus clouds in the neighbourhood of their centres follow the isobars. Then, as in the case of cyclones passing through Bass Strait, their rate of approach is slow, even slower than the preceding type. As they move inland the motion becomes somewhat erratic, and now and again even retrograde, owing to the tendency often displayed for new centres to form. Sometimes two foci may develop, one of which will probably be over the coast of New South Wales. Their seasonal frequency makes them an even more decidedly winter product than the preceding. Of the 34 storms dealt with no less than 32 occurred during the six months May to October, and only 2 in the summer half of the year, 1 in March, and the other in November. This is very remarkable, and worth noting in anticipating developments. The figures for each month are as follow :—January, 0 ; February, 0 ; March, 1 ; April, 0 ; May, 4 ; June, 4 ; July, 7 ; August, 8 ; September, 5 ; October, 4 ; November, 1 ; December, 0 ; giving a total for 18 years of 34.

July and August are, as before, the months of greatest frequency. The greatest number observed in any one year was 4 (1903 and 1911), and none were observed in the years 1898 and 1899. As regards the seasonal rainfall totals, their occurrence does not seem to have any marked effect, the assumption being the same as that just made in connexion with the previous type.

Only in two cases of the approach of these storms were Cirrus observations not obtained, a fact similar to what was just noted with regard to Antarctic cyclones passing through Bass Strait, and which further helps to differentiate them from ordinary Antarctic depressions.

In relating the Cirrus movements to storm distances previous methods have been used, except that eight observations have been given for the 1,700 mile distance. This is the distance from Melbourne to Cape Leeuwin, the extreme limit for the location of approaching storm centres, and it is not, of course, probable that Cirrus directions over Melbourne are really ever much affected by systems so remote.

The cloud directions obtained from the eight observations at this distance vary all the way from W. 55° S. to W. 39° N., these extremes being for the one storm, an intense Antarctic, hovering about Cape Leeuwin, where it apparently remained stationary for three days. The direction, W. 55° S., was probably the first direction due to the storm itself ; after that was obtained the veering was progressive.

The following table gives the results obtained :—

Distance of Storm Centre.	No. of Observations.	Mean Cirrus Direction.
1,700 miles	8	W. 19° S.
1,148 „	5	W.
978 „	9	W. 21° N.
705 „	12	W. 28° N.
574 „	12	W. 40° N.
331 „	11	W. 67° N.
116 „	7	N. 7° E.

In most cases where Cirrus was observed coming from points East of North, the barometric centre of the low lay in a North-westerly direction from Melbourne, but in six of these cases the centre was due West at distances varying from 50 to 900 miles.

Comparing the Cirrus directions with those for the cyclonic circulations passing through Bass Strait, the same tendency towards a Northerly Cirrus direction for these clouds even far in advance of the centre is very evident. Taking the 1,000 miles distances the latter type of cyclone shows Cirrus direction W. 16° N. as against W. 8° N. for the preceding one, both giving a much more Northerly direction than the Antarctics which average W. 14° S. when all are used, and W. 5° S. for those producing general rains. At 500 miles the differences are greater, W. 48° N. for the latter cyclonic type, W. 30° N. for the former, W. 14° N. for " Antarctic V's " in general, and W. 20° N. for Antarctic V's producing general rain. The 100-mile distance shows how complete is the cyclonic control of the upper circulation in these latitudes, the latter type of storm causing a mean Cirrus direction of N. 7° E. when the centre lies to North-west of the observer. Those passing through Bass Strait give for the same distance a mean direction of N. 43° W., a difference of 50°. The successive changes in cloud direction as the storm centre approaches are very progressive.

The following is a description of one of these storms typical in many respects, but barometrically more intense than usual.

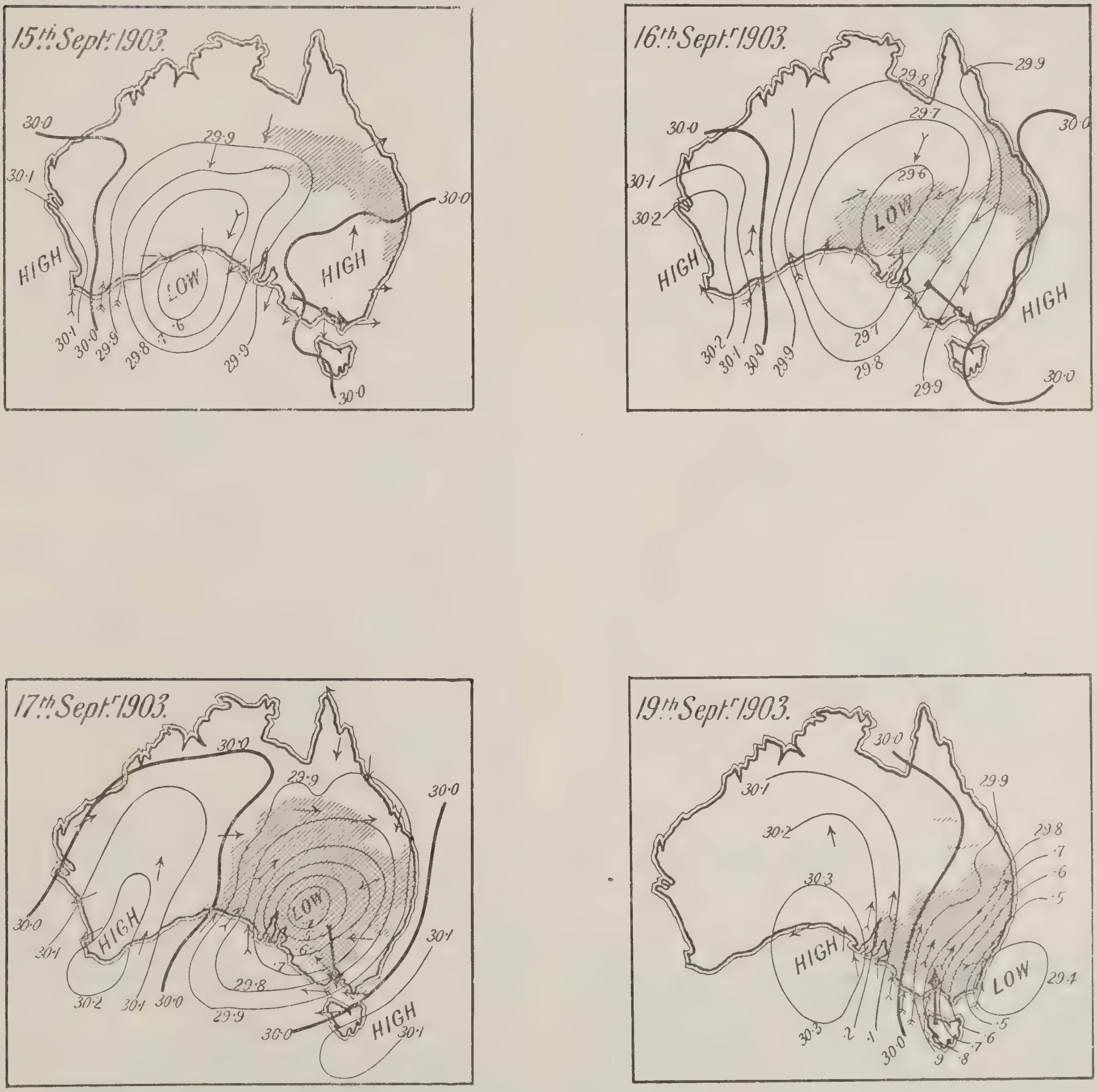
Typical Antarctic Cyclone passing inland over Victoria and New South Wales.

On the 14th September, 1903, an ordinary Antarctic V-depression had appeared South of Cape Leeuwin, the 29·8 isobar running parallel with the South coast-line and a 30·2 " high " inland from Shark Bay. In front of the storm lay a " high," 30·2 over Western Victoria and New South Wales. No cloud indication at Melbourne.

On the morning of the 15th light Cirrus was coming slowly from W. 14° N., and by noon dense and almost cumuliform patches were moving slowly from W. 38° N. The 9 a.m. weather chart of this date showed what appeared to be a cyclonic centre South from Eucla, where the barometer read 29·60 inches. This was supported by strong Southerly winds and rapidly rising barometer along the Western Australian coast-line, the reading at Cape Leeuwin being 30·1 inches. On the 16th the weather was still fine over Victoria. In Melbourne the barometer was only slowly falling, and the weather calm and nearly clear, but in the afternoon a bank of Cirrus appeared on the Northern horizon, woolly diffuse bands springing towards the zenith. These were moving from W. 26° N. The chart showed a definite cyclone centred over the interior of South Australia, where pressures were as low as 29·6 inches. On the 17th the sky in Melbourne was covered with heavy Cirro-stratus to Alto-stratus clouds extending almost to the Southern horizon, where the bank ended with a well-defined Cirro-stratus edge. A break in the cloud mass enabled the direction of Cirrus or Cirro-stratus clouds to be got at 11 a.m., when it proved to be only 15° West of North. From high level Nimbus coming from E.N.E. steady rain set in about 1 p.m., and continued for 24 hours. The chart for the 17th showed an intense cyclone centred North of Adelaide with readings below 29·4 inches. Heavy rain was then falling generally over South Australia, New South Wales, and North-western Victoria. On the 18th the storm centre had reached Gabo Island and was still deepening, giving there readings down to 29·10 inches. The afternoon of this day in Melbourne was fairly fine, and about 7 p.m. the Cirro-stratus on the Western edge of the bank of rain clouds was moving slowly from S.S.W. Next morning some thin straight fibred Cirrus, apparently of great altitude, was moving from South, the storm centre having moved further Eastwards, and the barometers at Gabo risen to 29·4 inches.

Below are printed partial copies of the weather charts, 15th–19th September, 1903. As before, the larger arrows show Cirrus direction, the smaller wind direction, and the shading the areas over which rain had fallen.

Type III.—Antarctic Cyclone passing Inland.



Small arrows indicate wind directions: bold arrows, the Cirrus direction over Melbourne; shaded areas, the rainfall distribution during the preceding 24 hours.

TYPE IV.—ANTARCTIC CYCLONES PASSING FROM BIGHT NORTH-EASTWARD INTO NEW SOUTH WALES OR QUEENSLAND.

These storms may be regarded as forming a kind of sub-class of the preceding, but as regards their effect upon Melbourne weather or Victorian weather in general, the difference is very great.

Nine storms of this type occurred during the eighteen years under review, and of these only three produced moderate to heavy rain, and this only in the North-west and North, while the remainder brought practically nothing to any part of Victoria. All, however, brought rains to South Australia and New South Wales, and six of them brought rain to Southern Queensland.

As with the preceding, they are entirely winter developments, their distribution in time being as follows :—January, 0; February, 0; March, 0; April, 1; May, 0; June, 0; July, 3; August, 3; September, 2; October, 0; November, 0; December, 0; year, 9.

They confirm the tendency previously noticed by the writer, see " Weather Types," in " Climate and Weather of Australia," for certain types to recur in certain seasons. In 1896 two occurred, one in July and one in August; in 1899, two, one in July and one in August; in 1903, two, one in August and one in September. This leaves only three for the other fourteen years, one in September, 1895, one in April, 1905, and one in July, 1911. The following map shows the path followed by these storms, the dots showing the location of their centres :—

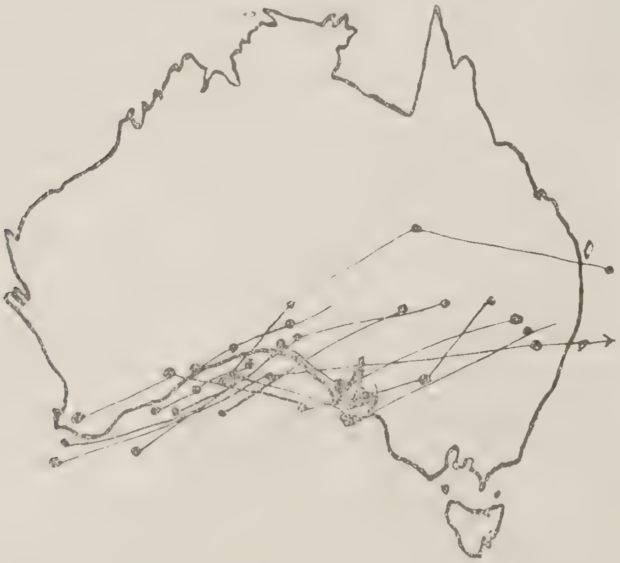


FIG. 2.—Tracks of centres of Antarctic cyclones passing inland in a north-easterly direction over South Australia.

The paths followed by these storms may be regarded as abnormal. In seeking for reasons for such deviation from the usual track the isobaric chart has not much to suggest. In three cases, however, during the approach of one from the Westward an intense high built up over Tasmania. This occurred with the two in 1899, and it is interesting to note that the building up of high pressure over Tasmania in this case appeared to be directly related to the Southward movement of a tropical " low " from the Gulf of Carpentaria, a relation not unusual. In fact, as regards the two Antarctic cyclones moving inland in 1899, it is probable that they did not really succeed in doing this, but that they died out over the Bight, and were not even merged in the tropical depressions which came Southwards in front of them. The weather chart made it appear so, but being made up only every 24 hours it is, of course, helpless to guide in such cases.

The following table gives in the same way as before the Cirrus directions over Melbourne for different distances of storm centres Westward from the meridian :—

Distance of Storm Centre (West from Meridian).	No. of Observations.	Mean Cirrus Direction.
890 miles	2	W. 1° N.
655 ,, ...	2	W. 20° N.
440 ,, ...	2	W. 8° N.
255 ,, ...	2	W. 2° S.
50 ,, ...	3	E.N.E. to N.N.E.

Daily rate of movement, Eastward component only, 525 miles.

The paucity of Cirrus observations is probably significant. Preceding cyclonic types yielded double the number per storm. The direction of Cirrus movement is also extremely variable and does not show at all the steady increase in the Northerly component noted with the other types. The tendency is, in fact, actually the other way, except that when the storm centre is North from Melbourne Cirrus is occasionally seen moving from directions between N.N.E. and E.N.E.

Only in one case when the storm centre was still over the Bight was Cirrus observed moving from a direction as much Northerly as is given as a mean result for preceding types.

The chief peculiarities in Cirrus movements in front of a cyclonic storm taking or about to take this North-easterly course appear to be as follows :—

(1) They are much more Southerly than in the case of cyclonic storms keeping an Eastward course.

(2) The rate of movement of Cirrus is slower than normal and direction irregular.

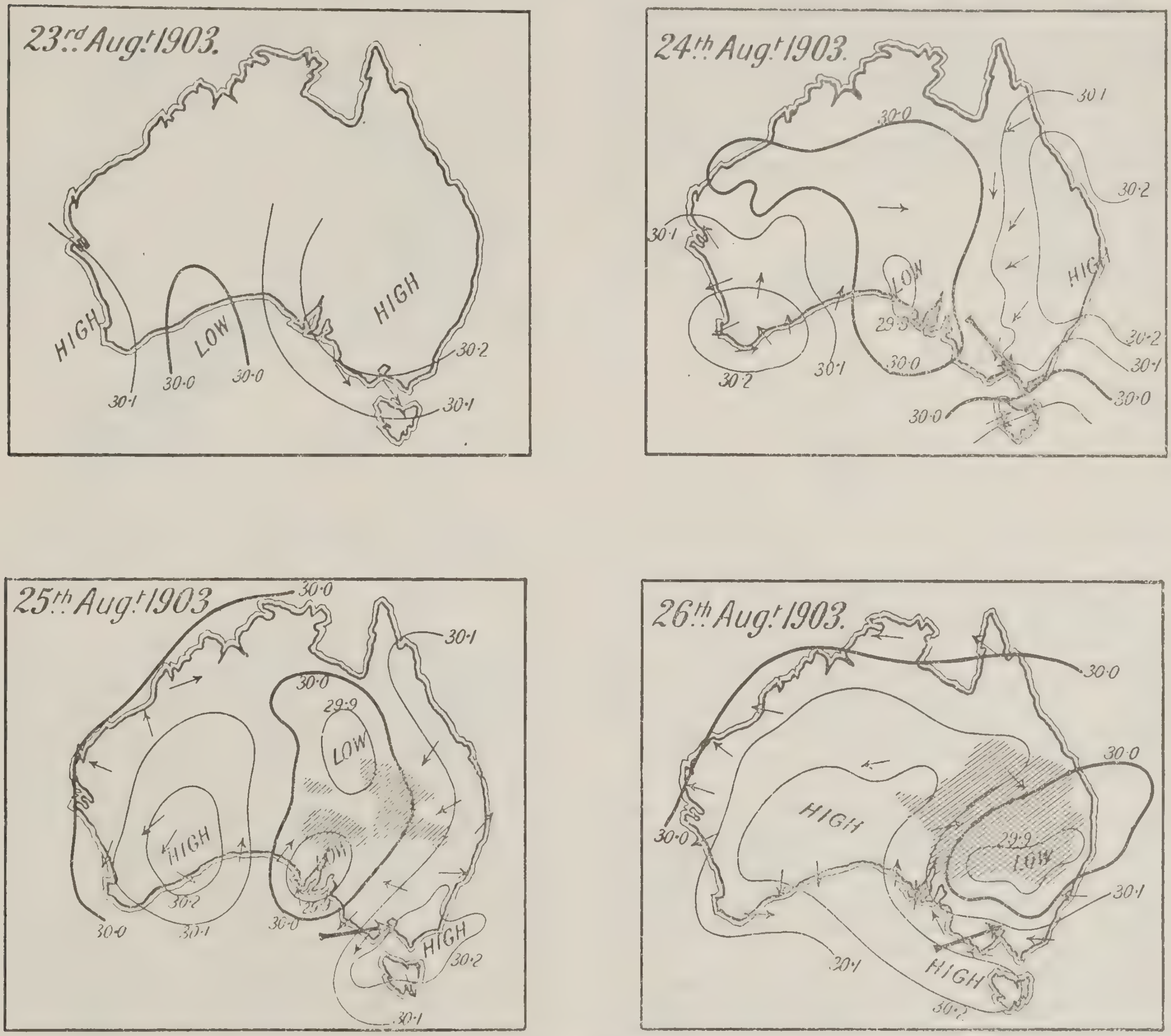
(3) The amount of Cirrus seen is less than usual.

It would, therefore, seem not improbable that the deflection Northwards when real is due to the upper air flowing not as usual in winter from a point between North-west and West, but from some point South of West, in which case the months in which they occurred would be likely to have a rainfall less than average. This was actually so over inland Victoria for seven months out of the nine in which these storms occurred. The rather rapid rate of translation of these storms also tends to show that the conditions under which they occur differ considerably from those favorable to the other cyclonic types.

The following is offered by way of theory.

If we conceive of the depression as resulting from the Southward flow of the upper air from tropical regions and the further progress of this upper air flow to be blocked by a stream from some Southerly point, flowing, say, North-eastward over Victoria and the South-eastern half of New South Wales, and if we assume poleward streams to give rise to convectional action and equatorward streams to have the reverse effect, the rainfall due to the poleward flow would be distributed along the North-western side of a line lying South-west and North-east, and running from South Australia or Western Victoria into Southern Queensland. The following maps show this fairly well:—

TYPE IV.—ANTARCTIC CYCLONIC DEPRESSION PASSING INLAND IN A NORTH-EASTERLY DIRECTION FROM THE BIGHT.



Small arrows indicate wind directions; bold arrows, the Cirrus directions over Melbourne; shaded areas, the rainfall distribution during the preceding 24 hours.

TYPE V.—CYCLONIC DEPRESSIONS ORIGINATING IN OR CROSSING THE WESTERN INTERIOR OF THE CONTINENT AND PASSING SOUTH OF MELBOURNE.

By this definition is meant storms of definitely cyclonic circulation which have drifted to Western Victoria from some point between West and North, generally after passing over West and South Australia, and in one case at least from the Northern Territory, but not storms which have previously had their centres of energy over any portion of Queensland or New South Wales.

Storms of this type are not frequent, only twenty occurring in the eighteen years. They originate variously. Two first appeared as cyclones off the North-west coast of Western Australia, where they are known as Willy Willies. These were both March storms, one in 1907 and the other in 1912. Most originated in shallow monsoonal "lows" over the North-western interior of Western Australia. Of these there were twelve. One came direct from the Territory; one originated quite close at hand East of Adelaide. Four seemed to originate somewhere between Coolgardie, Alice Springs, and Eucla, one of which apparently began as the result of an "Antarctic" dying out on reaching Esperance Bay. The fact that these storms originated in the usually dry Western interior, or, as in the case of the Willy Willies, were able to cross it, points to exceptionally favorable conditions for the time being, probably an extensive Southward drift of the upper atmosphere over this region.

In connecting Cirrus directions over Melbourne with these storms, the same method has been adopted as with the types previously dealt with, which, of course, involves ignoring the Northerly component of the distance of the storm centre. This may at first seem a serious defect, but it is probably not so, as it tends to show whether there is any special atmospheric drift favoring the Southward movement. The results obtained certainly support this assumption, as the following figures indicate :—

Distance of Storm Centre (West of Meridian of Melbourne).	Cirrus Direction over Melbourne.	No. of Observations.
1,224 miles	W. 17° S.	6
869 ,, ...	W. 6° N.	5
676 ,, ...	W. 15° N.	11
430 ,, ...	W. 29° N.	3
237 ,, ...	W. 87° N.	8
100 ,, ...	W. 81° N.	1

As may be seen, Cirrus directions prior to the advent of this storm type give a much more Northerly average for all distances up to 1,000 miles than in the case of approaching "Antarctics," although the actual distances to the storm centre are greater than the distances given, since these neglect the Northerly component, and the Northerly veering as the storm approaches is only exceeded in the case of Antarctic cyclones passing inland. This is significant, in view of the fact that most of these storm centres reach the sea West from Cape Nelson and pass as "Antarctics" over or South of Tasmania.

These storms almost invariably bring heavy rains to South Australia and Victoria, and usually do the same for inland New South Wales, and occasionally for a large part of Queensland. Out of the twenty, there were only three which might be classed as rain failures, all in very dry years, two in 1907 and one in 1901. Even in the case of these there was rain in South Australia and Victoria, but only light and scattered.

In time the distribution was as follows :—January, 1; February, 0; March, 3; April, 2; May, 0; June, 2; July, 0; August, 0; September, 5; October, 3; November, 3; December, 1. They seem, therefore, to be most likely to occur in spring, to a less extent in autumn, and scarcely at all in the winter and summer months.

Rate of Movement.—This, taking the Eastward component only, averages 400 miles per day, once the journey across the continent is begun. When they originate North of the tropic the movement is sometimes imperceptible for days at a time or retrograde, *i.e.*, towards the West or South-west. This has not been taken into account in averaging rate.

The energy of these storms is often considerable. The average of the lowest barometer readings indicated on the weather charts was 29·44 inches; one was as low as 29·10 inches, another 29·12 inches, and six were below 29·3 inches. These low readings were only registered on the South coast-line.

The map below shows the apparent paths followed by the various storm centres. The tendency to cling to the coast-line is very marked. This is probably due to greater humidity and lessened friction over sea as compared with the land surface, and may not truly represent the control of the air movement at levels of much elevation.

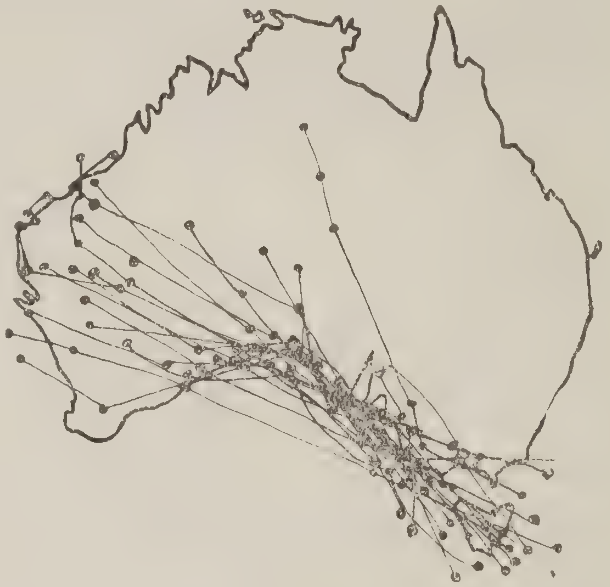
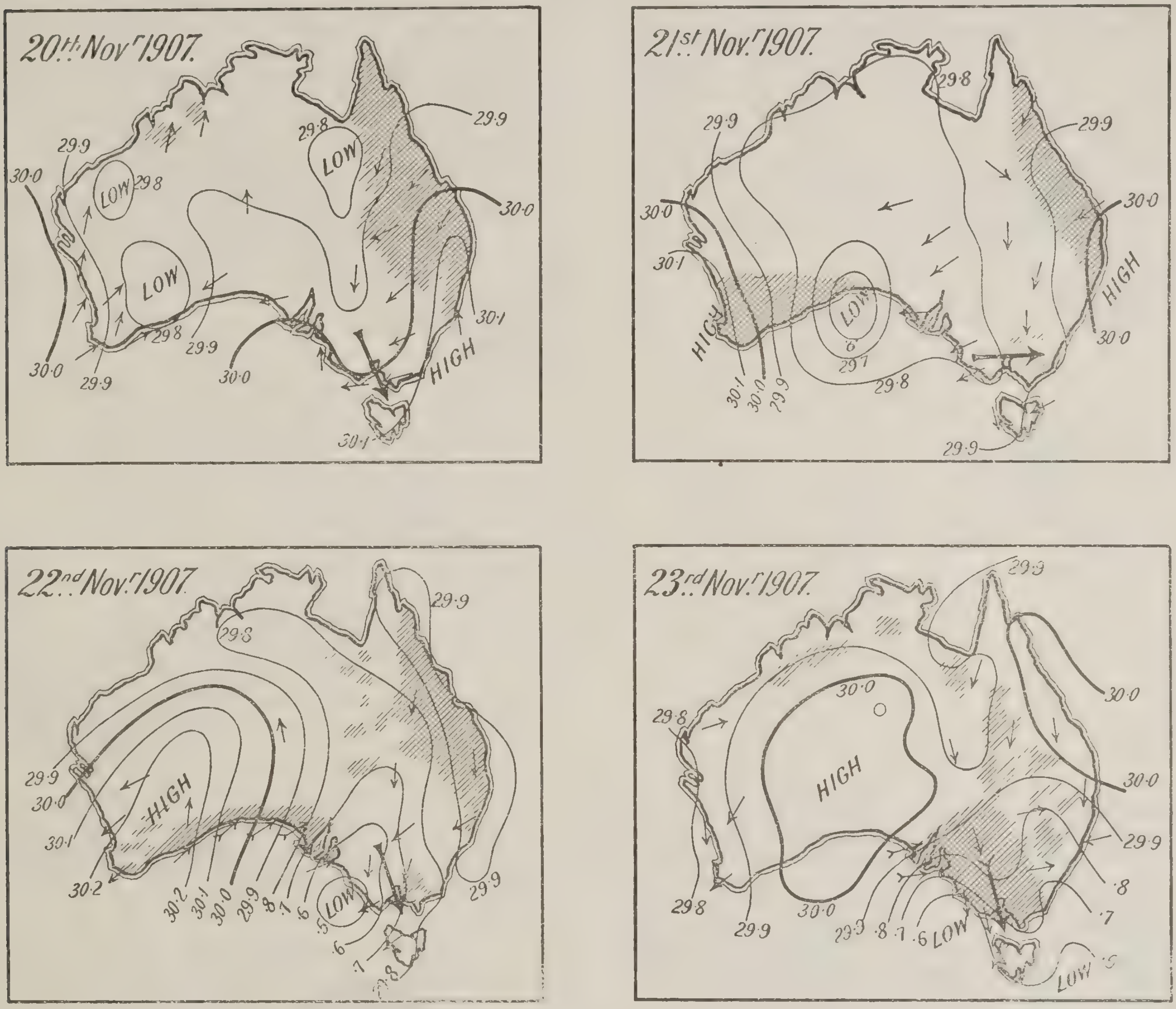


Fig. 3.—Tracks of centres of cyclonic depressions, originating in or crossing the Western interior of the continent, and passing south of Melbourne.

A very good example of this type of storm was shown 23rd–29th November, 1906. On the 23rd a very long and narrow trough of low pressure, below 29·8 inches, stretched from Geraldton, in Western Australia, to Port Darwin, while a large anticyclone, above 30·1 inches, covered the Bight and most of South Australia. Next day an oval depression below 29·7 inches was centred about Peak Hill, while the "high" covered the South-eastern quarter of the continent, and Cirrus clouds from W. 30° N. were passing over Melbourne. These clouds were, however, probably due to some other influence, as on the 25th, though the "low" was then centred about 400 miles North-west of Eucla, a "high" above 30·0 inches overlay Western Victoria, and Cirrus was moving from W.S.W. On the 26th the "low," below 29·8, lay about Fowlers Bay, and the "high," above 30·2 inches, much intensified, was centred South-west of Cape Otway. A good deal of Cirro-stratus was now passing over Melbourne, moving at 2 p.m. from W. 3° N., and, later, Alto-cumulus was coming over from the same direction, winds southerly. A little rain had fallen in the Western part of South Australia. On the 27th the "low," below 29·7, was centred about Port Lincoln, a very decided trough extending northwards into Western Queensland. The "high," above 30·2 inches, covered Tasmania and the East coast North to Clarence Heads, giving winds over Victoria an East to North-east direction. Clouds were plentiful and of several types, Cirrus from W.N.W., Alto-stratus W. 30° N., and Fracto-cumulus from North by East. Very little rain had as yet fallen anywhere. On the 28th an oval cyclonic depression, below 29·6 inches, stretched from Robe to Wilcannia, and heavy thunderstorm rains were falling over Victoria and New South Wales. The morning was very wet in Melbourne, several thundershowers falling, but at noon a break revealed Cirrus moving from N.N.E. Next day the weather was much finer, the whole circulation having become of Antarctic type, with low centre below 29·4 West or South-west of Tasmania.

The following series of charts was not the result of the storm just described, but of another which occurred almost exactly twelve months later. This was not quite so rain-productive, but maintained throughout its course an almost perfect barometric likeness to the preceding one, and the Cirrus movements over Melbourne were also very similar.

TYPE V.—CYCLONIC DEPRESSION FROM THE NORTH-WESTERN INTERIOR PASSING SOUTH OF MELBOURNE.



Small arrows indicate wind directions; bold arrows, the Cirrus direction over Melbourne; shaded areas, the rainfall distribution during the preceding 24 hours.

TYPE VI.—CYCLONIC DEPRESSIONS ORIGINATING IN OR CROSSING THE WESTERN INTERIOR OF THE CONTINENT AND PASSING NORTH OF MELBOURNE.

As regards mode and place of origin, these storms are much the same as those just dealt with, but they differ in the tracks followed by their centres, the latter either tending in a more Easterly direction or originating further East. The object of the writer in classifying these inland storms according as they passed South or North of Melbourne was to suggest by cloud data what part extensive upper air movements had in directing the paths of the storm systems. One difficulty encountered was due to the fact that in the neighbourhood of the storm centre, often for over 100 miles away from it, the circulation of the upper air appears to be complete, and hence the only difference between the effects of the two classes of storm when their centres were near Melbourne was that when the storm centre was West the Cirrus was from about North, rarely from North-east; and when the centre was North the Cirrus was from some point East of North. As the mean cloud directions here given for the various distances of storm centres from the Melbourne meridian are simply arithmetical means of the departures in degrees from the West point, it is obvious that giving full value to these Easterly movements confuses results, and tends to rob them of their significance. This effect will, however, be chiefly noticeable in the shorter distances, say, less than 200 miles,—not much in the greater distances.

The total noted under this head occurring during the eighteen years was 32, which, added to those passing Southwards West from Melbourne, gives a total of 52 for storms originating in or crossing the North-western interior of the continent and ultimately affecting Victoria.

On plotting the paths of the centres of these storms it became apparent that the definition adopted covered rather too much ground, inasmuch as some of the depressions followed fairly straight paths, while others changed direction. This made division into two sub-types necessary. The former (A) consists chiefly of storms originating near the centre of the continent, and, though moving in a South-easterly or East-south-easterly direction, passing generally North of Victoria, but in at least three cases passing directly over Victoria. These numbered 22. The latter (B), after moving East or South-east from the Western interior of the Continent to the Head of the Bight, then change direction in an East-north-easterly direction, thus following much the same average path as "Antarctic Cyclones passing North-eastward from the Head of the Bight into New South Wales or Southern Queensland." These numbered 10.

The following tables show the Cirrus relationships for these two sub-types :—

Distance of Storm Centre Westwards.	Cirrus Direction in Melbourne.	No. of Observations.
Sub-type (A).		
	°	
1,400 miles	− 1	6
890 „	+ 7	4
692 „	+ 10	6
430 „	+ 29	7
271 „	+ 89	4
21 „	+ 47	9
Sub-type (B).		
1,255 miles	− 25	6
887 „	+ 1	3
680 „	+ 16	3
488 „	− 3	3
282 „	− 50	2
140 „	+ 19	6

These results are interesting. The Cirrus directions for Sub-type (A) obviously bear a very close resemblance to those heralding the approach of "Cyclonic Depressions originating in or crossing the Western interior of the Continent, and passing South of Melbourne," and the resemblance is maintained until the Westerly component of storm distance from Melbourne has diminished to about 250 miles. It may change then. This clearly points to similar conditions for origin, although there is some considerable difference in the locus of the mean paths of the two groups.

Sub-type (B) gives equally interesting results. For this the Cirrus directions depart quite widely from Sub-type (A), but agree closely with those obtained from "Antarctic Cyclones passing from the Bight North-eastward into New South Wales or Queensland." Considering the small numbers of these storms dealt with, the agreement is remarkable. − 50° (W. 50° S.) for the 282-mile distance is an extreme result, but such must be expected when the numbers dealt with are so small, only two in this case. One of the two Cirrus directions observed was almost due South, and was, as a matter of fact, quite consistent with the weather chart, the "low" being forced nearly due North from South Australia by the advent of a large anticyclone over southern waters.

As rain bearers, those under Sub-type (A) were very efficient, bringing some rain in every case to all of the South-eastern States. Only in three cases was this very light for Victoria, and in five only was it generally light. From the remaining fifteen some moderate to heavy rains fell. For South Australia and New South Wales the results were better still, light to moderate rains being always reported, and heavy rains fairly often. Their seasonal distribution was as follows :—January, 0 ; February, 2 ; March, 0 ; April, 0 ; May, 1 ; June, 0 ; July, 3 ; August, 5 ; September, 1 ; October, 5 ; November, 2 ; December, 3 ; total, 22.

Sub-type (B) was much less effective as a rain producer. Only in two cases out of ten did the rains in Victoria deserve the term moderate ; the remainder were either light or inappreciable. South Australia only had two rain failures, and in New South Wales light to heavy rains fell every time, though they were rarely general. In time the occurrence of these storms was chiefly confined to the latter half of the year, August having 2 ; September, 1 ; October, 3 ; November, 3 ; and April, 1.

The average daily rate of movement (Easterly component only), taking (A) and (B) together, is 390 miles, which is practically the same as that of the preceding type. The average lowest chart barometer reading in connexion with these is 29·74, ranging from 29·50 to 30·05. This, however, neglects low readings on the coast of New South Wales, as the storm centre passes on to Eastern waters.

The charts attached show the paths taken by the centres of these storms.

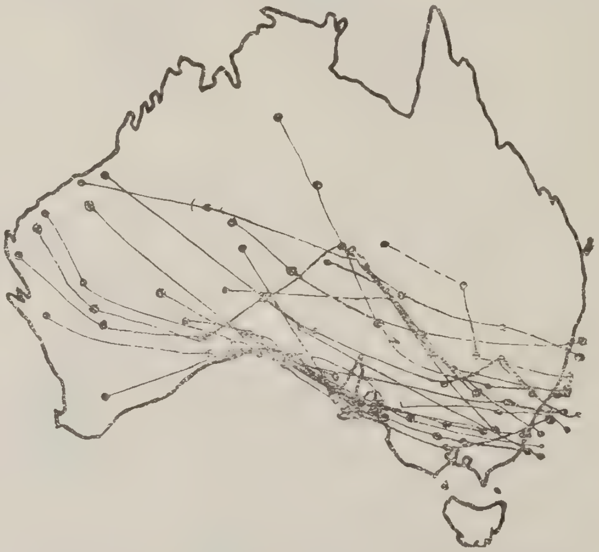


Fig. 4.—Tracks of Centres of Cyclonic Depressions originating in or crossing the Western Interior of the Continent and passing North of Melbourne. Sub-type A.

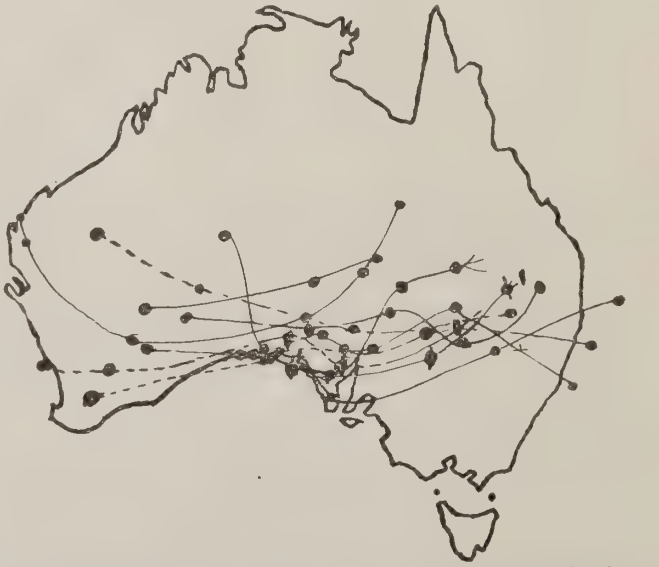
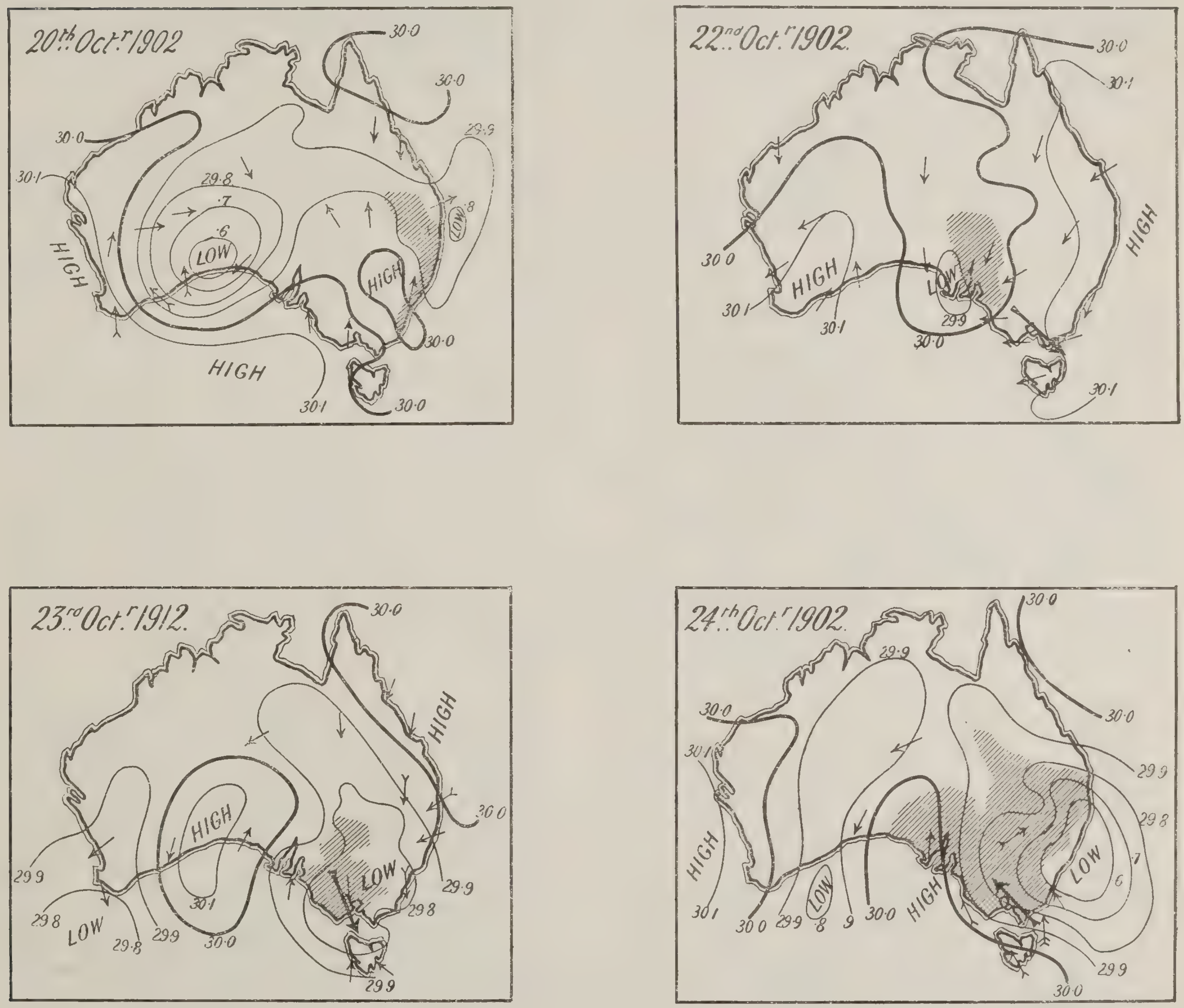


Fig. 5—Tracks of Centres of Cyclonic Depressions originating in or crossing the Western Interior of the Continent and passing North of Melbourne. Sub-type B.

The following weather chart copies illustrate the differences between the two sub-types :—

TYPE VI.—CYCLONIC DEPRESSION FROM THE NORTH-WESTERN INTERIOR PASSING NORTH OF MELBOURNE.

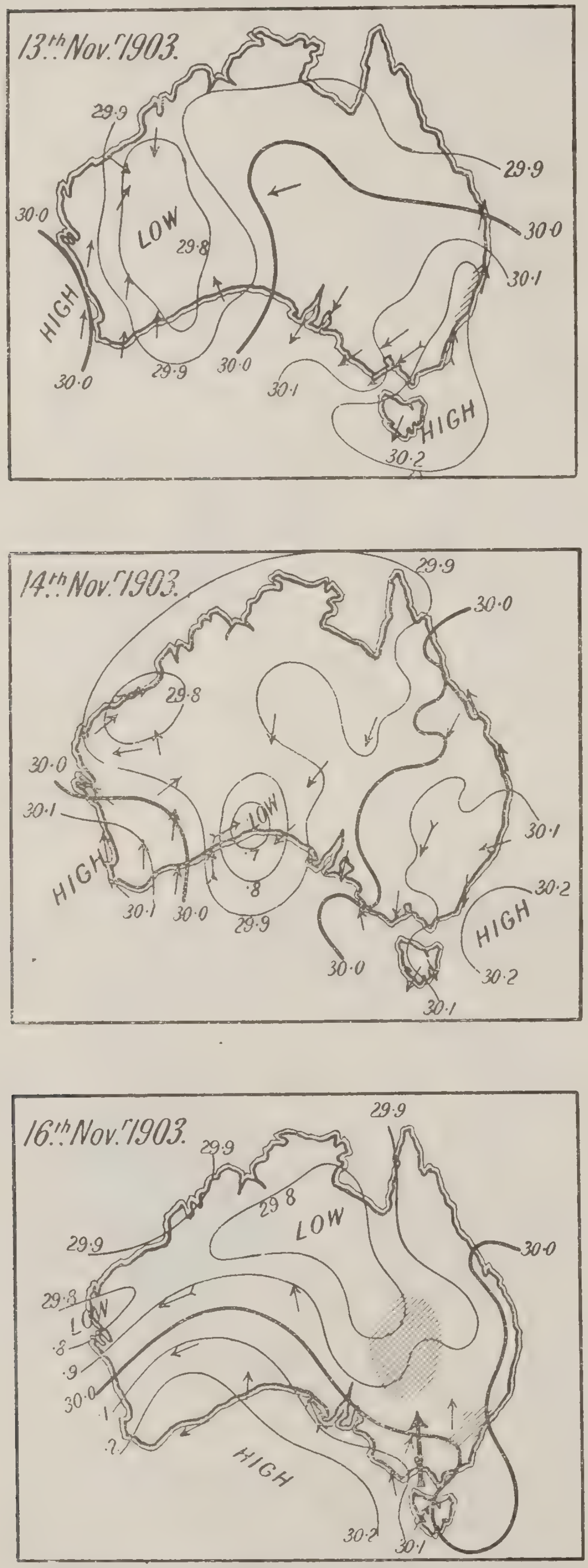
SUB-TYPE A.



Small arrows indicate wind directions ; bold arrows, the Cirrus direction over Melbourne ; shaded areas, the rainfall distribution during the preceding 24 hours.

Type VI.—Cyclonic Depression from the North-Western Interior passing North of Melbourne.

Sub-type B.



Small arrows indicate wind directions; bold arrows, the Cirrus direction over Melbourne; shaded areas, the rainfall distribution during the preceding 24 hours.

Type VII.—Tropical Depressions originating over Queensland and pressing Southwards.

These storms are not only most interesting to a meteorologist, inasmuch as their genesis and often their complete history may be shown isobarically, but they are among the most effective rain producers visiting the Eastern half of Australia. From the point of view of this paper they are easily first in interest, owing to the very decided way in which their development and progress are indicated by Cirrus movements as far South as Melbourne. Few weather signs approach infallibility, expecially as regards rain production, but the sudden appearance of Cirrus clouds moving over Melbourne from a point between North-west and North-east in fine weather with high barometers may be taken as a practically certain indication of rain falling or about to fall extensively over New South Wales, especially the Eastern half, and Southern Queensland.

For these storms in their beginnings barometric indications are practically nil. The weather chart usually presents only an extensive high pressure system centred over or South of South Australia or Victoria, with a moderate fall of pressure towards the North, the isobars over Northern Australia lying East and West. Sometimes, as in June, 1912, the first indication will be isolated rains over some area near the Western or Southern border of Queensland. These or cloud production rapidly increase in intensity and area, and extend southwards into New South Wales—sometimes, but rather rarely, into South Australia. Concurrently with this pressures fall in such a way as to cause the isobars to dip Southwards, eating, as it were, into the "high." At this stage the rains usually fall most heavily and over the greatest extent of country, not infrequently over the greater part of inland Queensland and New South Wales. The next stage, provided progress Southward continues and no "Antarctic low" interferes, is the formation of a cyclonic depression in the Southern part of the rain area. If very slight, this will not interfere with the monsoonal character and distribution of the rainfall, but if intense the rains tend to become limited inland to the North-eastern half of the area covered by the cyclonic circulation. The greatest cyclonic intensity is usually reached off the coast of New South Wales, where, owing to the arrangement of land and water, the heaviest rains fall South of the storm centre, being carried by South-easterly winds.

Cirrus movements over Melbourne give very emphatic evidence that the necessary condition for the development of these storms is a great atmospheric current flowing Southwards over inland Australia. The depth of this may perhaps vary, and in its inception possibly only the upper air may be affected. At all events the Cirrus drift Southward usually precedes that of lower air strata by a considerable interval, but the heavy rainfall occurs when the air current has a fairly uniform Southward drift for a depth of, say, 20,000 or 25,000 feet, or from, say, the base level of ordinary Nimbus to that of the Cirrus clouds. This is easily seen from observations taken in Melbourne, where, though Cirrus is seen moving from a Northerly point, no rain or other cloud development may follow, these being limited to areas perhaps 100 or even 300 miles further North. In case the heavy rains do reach Melbourne, it will be found that the cloud control has become practically uniform, though low scud from the South carried by a surface indraught towards the low pressure system forming inland is fairly frequent.

In dealing with the relation between the Cirrus directions over Melbourne and the position of the storm centre, there is in the early stages some difficulty, inasmuch as the Cirrus is often seen with its decided Southward drift before there is any isobaric indication of a storm forming inland, and even at a later stage when the isobars begin to show their characteristic Southward dips it is not possible to locate the centre of energy. This being so, the only practicable method appeared to be to assume the area of greatest barometric fall to be the centre of energy, and as far as possible this was done. When the cyclonic stage was reached the circulating centre was taken. The storm distances given are in this case the actual distances which may be taken as Northward, the variations from true North being usually inconsiderable, except when the storm centre was close at hand, in which case the Cirrus direction was usually that due to a cyclonic system. It should also be pointed out that the mean Cirrus directions obtained from the different storm distances have their significance appreciably diminished by the fact that in some cases, especially when the centres of action were remote, Cirrus movements over Melbourne were still being influenced by the ordinary "Antarctic" drift. But whether allowance is made for this or not, the figures obtained leave no reasonable room for doubt as to the nature of the upper air movements characteristic of this particular storm type.

The following table gives the results obtained :—

Distance of Centre of Energy	Cirrus Direction.	No. of Cirrus Observations.
1,120 miles	W. 44° N.	14
920 ,, ...	W. 69° N.	9
700 ,, ...	W. 61° N.	17
550 ,, ...	W. 70° N.	8
140 ,, ...	N. 6° E.	5
0 ,, ...	W. 70° N.	3

To realize the significance of these figures it is only necessary to compare them with those previously obtained for the two types in which the translation of the storm centres was from South-west to North-east, namely, "Antarctic Cyclones passing from the Bight North-eastward into New South Wales or Queensland," and "Sub-type (B)" of "Cyclonic Depressions . . . . passing North of Melbourne." It will be seen that for storm centres located over, say, South-western Queensland or North-western New South Wales, Cirrus directions over Melbourne in the case of the storm type now under discussion average from 60° to 70° further North in their directions than in the case of either of the types mentioned. Moreover, the practical constancy of the Cirrus direction over Melbourne while the storm centre is covering 1,000 miles in its Southward journey is a very suggestive fact. It may be noted, too, that in the case of the last there is less effect upon Cirrus movements due to any cyclonic circulation which may have been set up in the final stages of the storm's history.

As the list of storms under this head is a complete one, a few other points of interest in connexion with them may be noted.

(1) *Rain Production.*—The rains accompanying these disturbances are usually widespread, and on a very liberal scale. The State most favoured is New South Wales, which received good and generally heavy rains from 33 out of the 34 storms of the type occurring during the eighteen years. Queensland came next with 25, then Victoria with 22, and South Australia with 13. In the case of South Australia, this number applies only to Eastern portions, the record for the Western being much less. This is, of course, to be expected, as storms originating in Western Queensland will need to extend their influence Westward or travel westward to affect South Australia, and this will naturally be of rare occurrence.

(2) *Seasonal Frequency.*—The numbers were distributed over the different months as follows :—January, 3 ; February, 5 ; March, 6 ; April, 2 ; May, 5 ; June, 2 ; July, 1 ; August, 4 ; September, nil ; October, 3 ; November, 2 ; December, 1. This summary does not support the idea that because these storms apparently originate within the Northern interior of the continent they are of monsoonal origin. The excess in the summer half of the year (19 from November to April, as against 15 from May to October) is so small that it is better to assume a purely tropical origin for them.

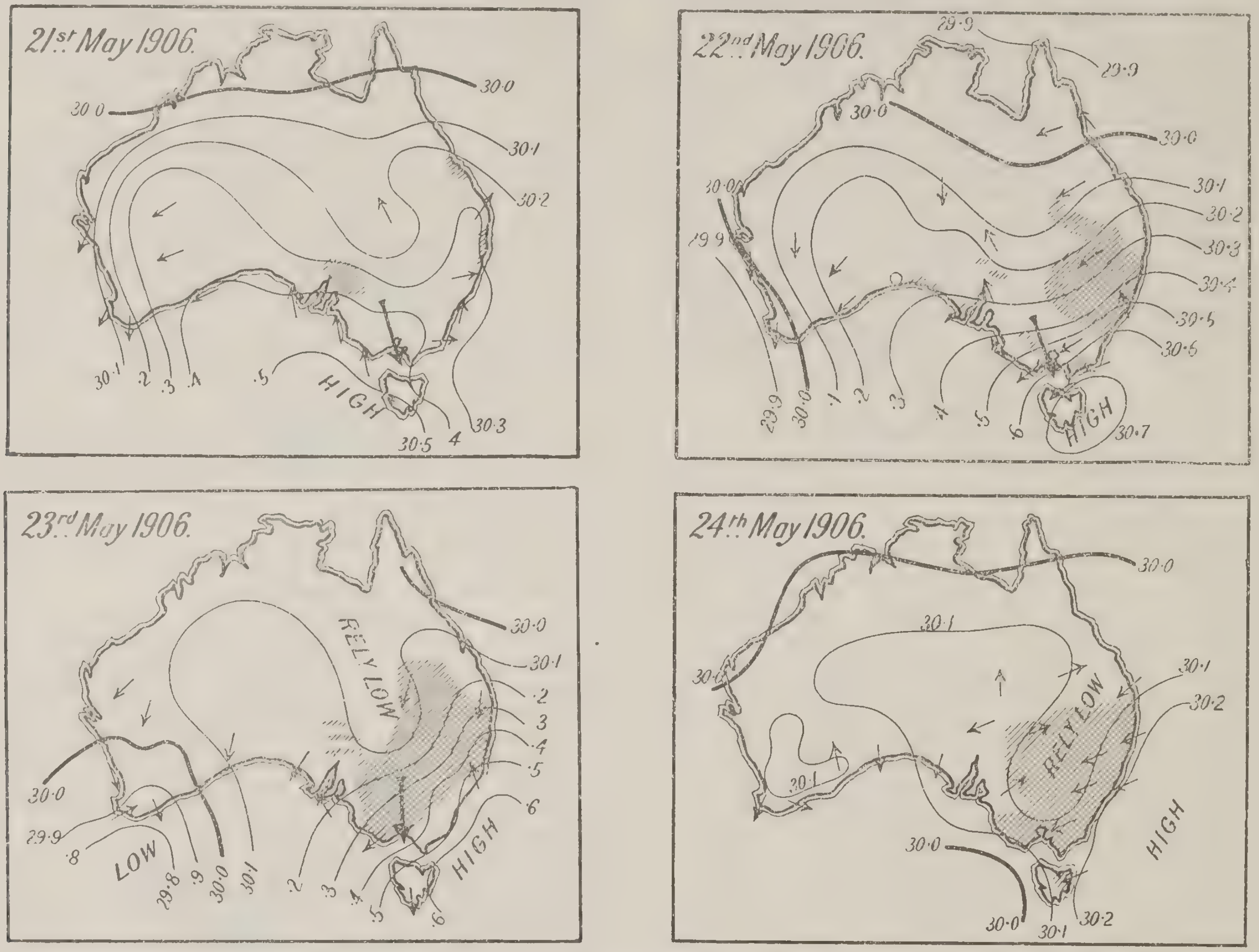
Since the total number occurring in eighteen years is 34, the average number per annum is approximately 2, but the numbers vary during the period from 5 in 1905 and 1908 to none in 1895, 1897, and 1902. It is very interesting to note that the so-called drought years, 1895–1902 inclusive, averaged exactly 1 per annum, while the following eight years averaged nearly 3 (22 for eight years). This suggests the importance of air flows from the tropical belt in promoting good rainfall.

A most striking example of the control exercised by upper air movement upon storm development beneath is given by the experiences of 20th–29th February, 1908. On the 20th an ordinary "Antarctic low" had just passed Eastward over Tasmania and a considerable "high" had taken its place, barometer readings exceeding 30·1 over Southern parts from Sydney to Esperance Bay, and 30·3 inches on the Victorian coast-line. A well defined isobaric "dip" below 30·0 inches lay over Western Queensland. Next day saw but little change in pressure distribution, except that the "high" was apparently centred over Tasmania. Cirro-stratus was in considerable amount over Melbourne, moving very slowly from W. 43° N. about 10 a.m. and W. 50° N. at 2.30 p.m. The only rain reported was from the North-eastern half of New South Wales, where it was fairly heavy. The 22nd showed as change only a slight dipping of the isobars Southwards towards Broken Hill. Cirrus and Alto-cumulus clouds were moving very slowly from N.N.E. and North over Melbourne. Rain was still falling in the North-east of New South Wales. Next day was Sunday, and no chart available, but Cirrus was moving from N.N.W. over Melbourne and heavy Cumulus plentiful. On the 24th Cirrus was from due North over Melbourne, and light to heavy rains had fallen over the Mallee and Wimmera districts in Victoria, and very heavy rains on the North coastal district of New South Wales, due in this case, however, to a cyclonic development off the coast-line. The "high" was now centred over the Southern areas of Tasman Sea, but extended as a high pressure ridge well towards Alice Springs, the "dip" still showing, but being less decided.

For the next three days this type of pressure distribution remained unchanged, and up to the 25th rain still fell heavily in North-eastern New South Wales, and at scattered places in Western Victoria. No Cirrus was seen on the 25th, but on the 26th and 27th wisps were coming over from due South. Coincidently with this the rain ceased in Victoria, and became limited to the coast-line in New South Wales, to which South-easterly winds still brought showers. During this period no rain fell or even threatened to fall in Melbourne, but the significant point is this, that inland conditions favoured rain while the Cirrus was from North and the reverse when from South, though isobaric contours underwent no appreciable change.

The weather charts of 21st–24th May, 1906, printed copies of which are reproduced below, are very typical of the developments of these Southward moving tropical influences. The constancy of its Cirrus direction over Melbourne is very well illustrated.

TYPE VII.—TROPICAL DEPRESSION ORIGINATING OVER QUEENSLAND AND PRESSING SOUTHWARDS.



Small arrows indicate wind directions; bold arrows, the Cirrus direction over Melbourne; shaded areas, the rainfall distribution during the preceding 24 hours.

TYPE VIII.—CYCLONIC STORMS OFF THE COAST OF NEW SOUTH WALES.

This type of storm is a very important phenomenon on the coast-line of New South Wales, producing there effects always very appreciable and often very sensational in their character. The rainfall south from the centre is nearly always heavy, as, in addition to the strong convectional action near the storm centre, the winds on the South side are blowing from off the comparatively warm ocean waters washing the New South Wales coast-line, and are, therefore, heavily moisture-laden. Moreover, the tendency for the production of steep barometric gradients, owing to the temperature and humidity difference between land and water, is so great that very violent gales are a common accompaniment. That the permanent warmth and consequently large evaporation from these Eastern waters as compared with the adjacent land surface is one cause of the very marked tendency apparent for cyclonic storms to form and persist there is evident in several ways, one of which is their greater frequency in winter, another that they are not nearly so frequent or persistent off the East coast of the North Island of New Zealand, and another that there is usually a very decided drop in the barometer of 1 to 3 tenths of an inch when one of these storms is formed by the passing of a monsoonal or cyclonic depression from off the land to the Eastern seas.

In the selection of these storms only those have been taken for which the chart isobars indicate centres actually off some part of the New South Wales coast-line and so near it that the scope of the storm does not include New Zealand. This has involved the rejection of some disturbances which, in conjunction with intense "highs" to West or South-west of their centres of energy, have caused heavy rains and possibly severe gales along the New South Wales coast-line.

The total number of storms thus eligible for selection during the nineteen years 1895–1913 was 88. The annual totals varied from 1 in 1895 and 1906 to 9 in 1899 and 1913.

They originate in one of three ways:—

(1) From depressions formed inland or passing across the interior of the continent, these being almost invariably very weak in their isobaric development compared with what they become after reaching the New South Wales coast-line.

(2) From "Antarctic lows," in some cases by the bodily Northward movement of the whole storm from off the East coast of Tasmania, and in others by the intensification locally of the Λ-shaped Northern portion of an "Antarctic low" which, centred much further South and continuing its Eastward movement, finally allows its offspring an independent existence.

(3) From tropical disturbances originating over the ocean East of Queensland.

The first is the most frequent, numbering 40 or nearly half the total number; then come those originating from "Antarctic lows," numbering 29; and, lastly, those originating from oversea tropical lows, these totalling 19.

That these storms are mainly a winter product may be seen from the following table, which give the totals for the nineteen years, including 1913, of each origin for each month :—

Month.	Inland.	Antarctic.	Tropical.	Totals.
January	3	0	1	4
February	1	1	1	3
March	2	1	0	3
April	1	3	3	7
May	6	3	5	14
June	5	9	2	16
July	6	5	3	14
August	5	4	1	10
September	4	0	2	6
October	2	3	0	5
November	3	0	0	3
December	2	0	1	3
				88

As might be expected the Antarctics are the most distinctly winter type, but both the others show the same partiality in only a slightly less degree. This again seems hardly to bear out the idea that many of the storms originating inland and affecting the Southern States are really of monsoonal origin.

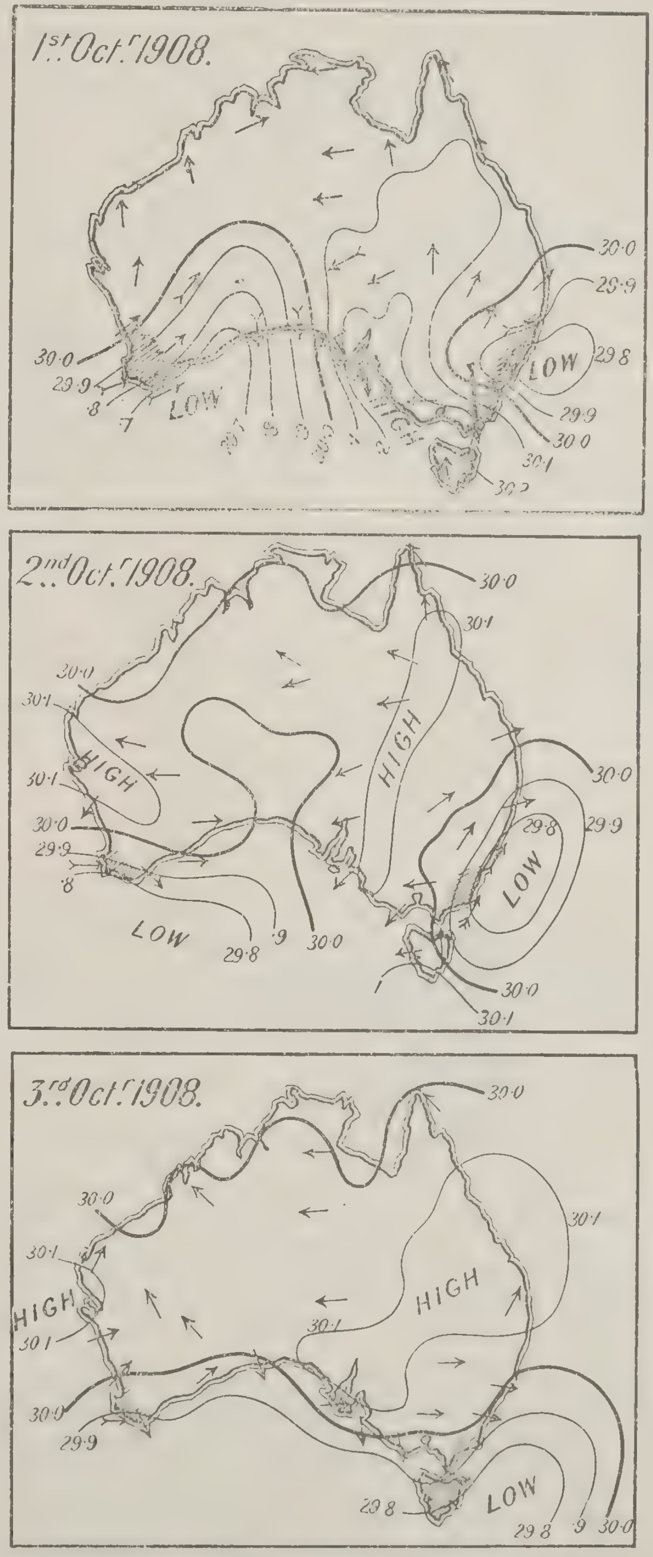
Effect upon Cirrus Movements.—Storms definitely cyclonic off the New South Wales coast are very prone to build up a semicircular high pressure system on their Southern side overlying Tasmania, Victoria, and the inland parts of New South Wales and South Australia, the axis of which usually passes over or near Melbourne. This means dry weather almost everywhere except in the Eastern part of New South Wales and clear skies over Melbourne, so that Cirrus is not very frequently observed, at all events in connexion with these disturbances. Should the storm centre lie South from Sydney, the usual Cirrus movement is from the South-east, and obviously due to the storm's own circulation, but there are not wanting evidences similar to those given in the previous section ("Tropical depressions pressing Southwards from Queensland") that the movement of the storm system itself is influenced by the drift of the upper air. The writer has found ten cases in which Cirrus, clearly the result of the same influence responsible for a cyclonic storm off the coast of New South Wales, was moving over Melbourne from the North. This is very striking evidence, as, this observation being made in the rear of the storm after the centre had become established off the New South Wales coastline, the circulation proper to the cyclone would give a very different result. The proof would not be complete without evidence that the appearance of Cirrus moving from some point between South and South-west, these not being the result of the storm's own circulation, was coincident with a reversal in the direction of movement of the storm centre. There are no less than eight cases of this, though there was one case in which the evidence was contradictory, that is, the storm's movement was Southward though Cirrus was seen moving from a Southerly point. To the previous cases there was no clear exception, one or two apparent exceptions being complicated with the circulation of inland depressions moving Eastward over New South Wales.

In at least two cases the double proof was available, that is, when Cirrus was seen coming down from the North the storm was moving Southwards, and when the Cirrus reversed its direction of motion the storm did the same.

A very interesting case occurred on the 1st October, 1908. A cyclonic storm, apparently of Antarctic origin, had formed on the New South Wales coast three days previously, with such steep gradients and straight North and South lying isobars in the rear that strong Southerly winds and very cold weather were experienced over Eastern New South Wales. Up to the 1st October the storm centre lay off Sydney. On that day Cirrus was observed in Melbourne moving Southwards, quite contrary to what one would have expected, and next day the storm was off Gabo, and by the 3rd had become an "Antarctic" off Tasmania.

The chart copies below show this Southward movement. It is interesting to note how the Antarctic V-depression West of the Bight on the 1st suffers the usual fate when a cyclone lies close to the East coast.

Type VIII.—Cyclonic Depression off the Coast of New South Wales.



Small arrows indicate wind directions; bold arrows, the Cirrus directions over Melbourne; shaded areas, the rainfall distribution during the preceding 24 hours.

SUMMARIES.

TABLE 1.—VARIATIONS IN CIRRUS DIRECTIONS OVER MELBOURNE WITH THE APPROACH OF THE DIFFERENT STORM TYPES.

Distances.	Antarctic V-Depressions.	Antarctic Cyclonic Depressions passing—			Inland Cyclones from the North-west passing—			Tropical Depressions pressing Southward from Queensland.
		(1) Through Bass Strait.	(2) Over Victoria.	(3) North-east-ward from Bight.	(1) South of Melbourne.	(2) North of Melbourne.		
						Sub-type (A).	Sub-type (B).	
	°	°	°	°	°	°	°	°
1,300 miles	..	..	..	..	..	..	..	..
1,100 ,,	(− 18)	..	+ 5	..	− 9	..	− 14	+ 46
900 ,,	− 10	(+ 22)	+ 23	+ 0	+ 4	+ 7	+ 0	+ 68
700 ,,	0	+ 47	+ 28	+ 16	+ 14	+ 10	+ 15	+ 61
500 ,,	+ 14	+ 30	+ 48	+ 11	+ 25	+ 24	− 2	+ 67
300 ,,	+ 25	+ 44	+ 71	− 1	+ 67	+ 77	− 46	+ 86
100 ,,	+ 35	+ 47	N. 10 E.	+ (?)	(+ 81)	+ 60	+ (?)	+ 88

TABLE 2.—MONTHLY TOTALS FOR THE VARIOUS STORM TYPES DURING THE EIGHTEEN YEARS 1895–1912 INCLUSIVE.

Months.	Antarctic V-depressions.	Antarctic Cyclonic Depressions passing—			Inland Cyclones from the North-west passing—			Tropical Depressions pressing Southward from Queensland.	Cyclones off the New South Wales Coast.
		(1) Through Bass Strait.	(2) Over Victoria.	(3) North-east-ward from Bight.	(1) South of Melbourne.	(2) North of Melbourne.			
						Sub-type (A).	Sub-type (B).		
January ..	68	4	0	0	1	0	0	3	4
February..	57	1	0	0	0	2	0	5	3
March ..	66	3	1	0	3	0	0	6	2
April ..	73	5	0	0	2	0	1	2	5
May ..	59	7	4	0	0	1	0	5	10
June ..	56	7	4	0	2	0	0	2	15
July ..	62	13	7	3	0	3	0	1	14
August ..	70	8	8	3	0	5	2	4	10
September	86	7	5	3	5	1	1	0	5
October ..	92	3	4	0	3	5	3	3	5
November	97	2	1	0	3	2	3	2	3
December	89	2	0	0	1	3	0	1	3
Totals ..	875	62	34	9	20	22	10	34	79

COMMENTS ON TABLES 1 AND 2.

In Table 1, by the aid of a little interpolation, the average Cirrus direction observed during the approach of various storm systems is shown for the same distances, these being the West component in every case but the last, for which they represent distances to Northward.

Table 2 shows the total number per month for each type of storm occurring during the eighteen years.

Attention may be drawn to the chief points of interest in these.

That the two types of Antarctic cyclones, one passing through Bass Strait, the other over Victoria, are under the same atmospheric control is obvious, their Cirrus effects strongly suggesting that upper air drift from lower latitudes is responsible for their production. The divergence in results for the short distance, 100–300 miles, is the natural result of the circulation of the storms themselves.

The agreement between the Cirrus direction for two storm types originating or passing over the Western interior of the continent is equally marked, and the fact that the Cirrus directions agree for the various distances in spite of the difference between the mean paths of the two types points again to their being merely incidents in a much wider upper air current from the North-west.

Equally significant is the agreement between the results from the two types of cyclones following a North-easterly course after leaving the Head of the Bight. Their deflection Northwards is concurrent with a most marked Southerly deviation in Cirrus direction over Melbourne. As their track maps show their life is a comparatively short one, and few succeed in crossing the continent.

The last column shows average Cirrus directions over Melbourne as a centre of energy approaches from the interior of Queensland. These are much the most northerly of all, and show remarkably little change as the storm approaches. It, in fact, seems probable that, if we could eliminate in the early stages those movements produced by other influences, and in the later those due to the cyclonic circulation frequently developed, there would be but little difference between the results for the least and greatest distances of the centre of energy.

Table 2 is of interest mainly as showing when each type has its greatest probability of development.

CIRRUS MOVEMENTS AS GUIDES TO PRESSURE CHANGE OR STORM DEVELOPMENT.

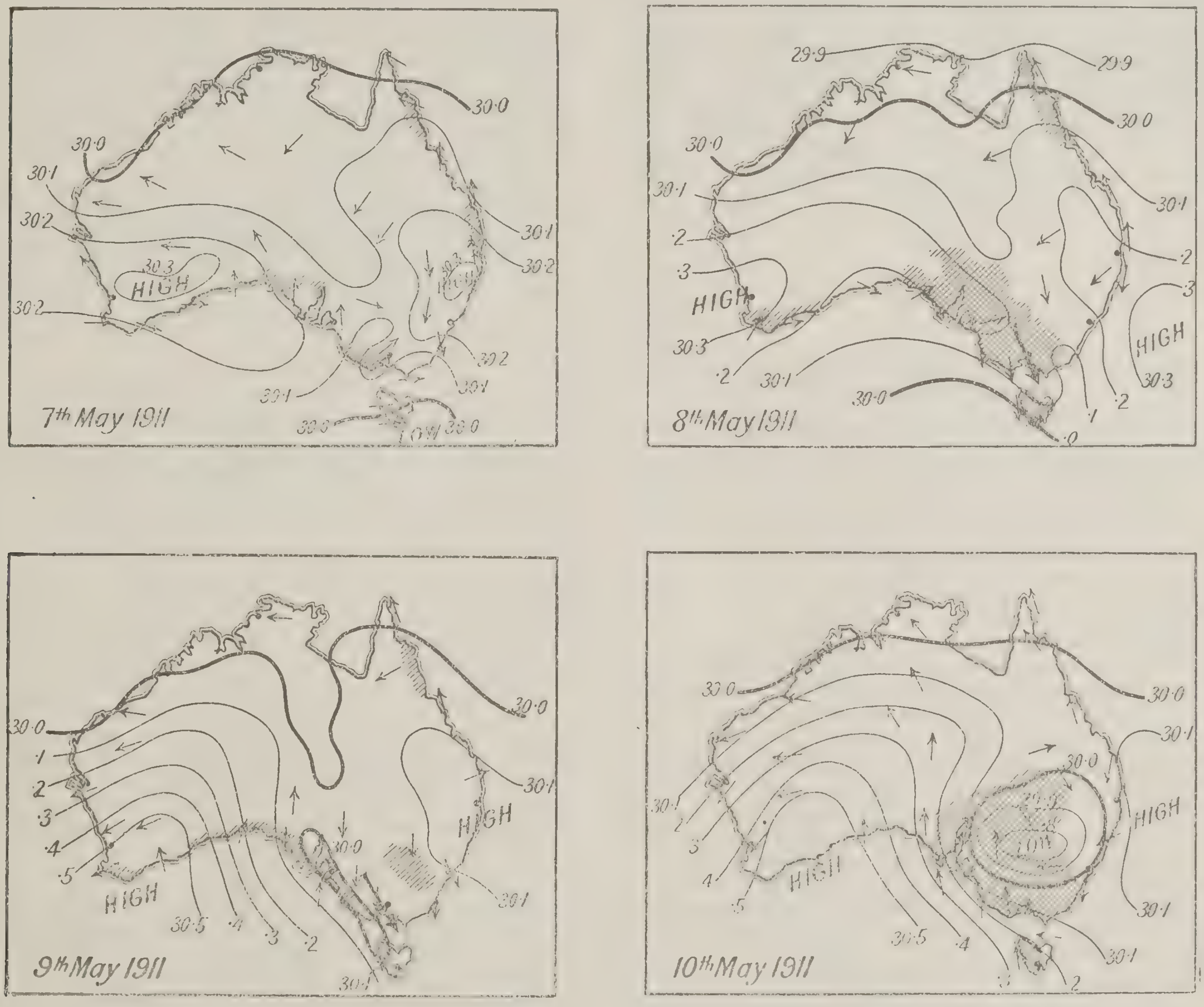
This paper would not be complete without reversing the process hitherto adopted, and instead of showing what Cirrus movements may be expected over Melbourne as the results of certain pressure and rain developments, show what pressure and rain developments may be expected from certain Cirrus movements. That, when used in conjunction with the daily isobaric chart, they supply most valuable information in connexion with the various storm types has already been shown. It may also be shown that under certain circumstances they may be allowed to stand practically alone as guides to the following weather, although, of course, as in the case of all other data, intelligence in application can hardly be dispensed with, and the more factors known the better the forecast should be.

The significance of Cirrus movements is best seen by selecting instances where there is a marked difference between the Cirrus directions observed and those usually induced by the low-pressure system assumed to be controlling the local air circulation.

The following are not infrequent examples :—(1) The passage of an ordinary Antarctic V-depression is usually accompanied by a very considerable change in upper cloud direction, the Cirrus when the trough is approaching generally backing from South-west to some point between West and North-west but soon veering to some point South of West after the trough passes. But if, when the trough has got sufficiently far Eastward to allow of this Southerly veering Cirrus is observed to be coming from a point well North of West, and especially if moving rapidly, a new development of some magnitude may be safely predicted. Long experience had created this impression very strongly, but to prove its reality the records since 1898 have been carefully examined. The results entirely confirm the impression formed. The number of clear cases noted during these years was 22. Of these, eleven preceded the formation of a second Antarctic V-depression South of South Australia, or an apparent retrograde (Westward) extension of the "low," so as to eat away the front of the advancing "high," and all were followed by light to heavy rains over Victoria, frequently including South Australia and New South Wales. In ten of the cases the centre of the depression was not formed South of the coast-line but inland, generally in connexion with a monsoonal-like trough. Extensive rains also followed these, with only one exception, and even then rain fell over the North-western and Central-western slopes of New South Wales. The remaining case was that of a monsoonal trough, which made an apparent Westward movement, this also being accompanied by good rains.

There are good grounds for thinking that in practically all of these cases, a common cause is operative although the effects are apparently somewhat diverse. The formation of the inland "low" may be taken to be due to the same cause as that already given for inland depressions generally, namely, an extensive Southward drifting of the air, possibly confined at first to upper levels, but later extending to lower levels also. The storm centre being retained inland is probably occasioned by the advent of an intense anticyclone passing South of the continent over ocean waters. But should there be after the passage of the low pressure trough still a tendency to falling barometers as we go Southwards from the coast-line, the effect of the upper air flow from the North will be the local intensification of the "low" to Southwards and the formation of a "secondary" Antarctic in the neighbourhood of the observer. A very favorite position in our case is over the ocean waters off Robe.

The weather of May 7th to 10th, 1911, the charts for which are printed below, give an interesting example of the significance of continued Cirrus movements from a Northerly point after the barometric trough has passed. The 7th was a cloudy and wet day in Melbourne, and no Cirrus observations were possible, but by noon of the 8th the weather became fine, and Cirrus on the Western edge of the cloud bank was seen to be moving from N.N. West. The 9th was cloudy but fine, and during the afternoon breaks in the low clouds revealed Cirrus coming over from points between N.W. and N.N. West. The widespread inland rains and cyclonic development which followed are evident from the weather charts.



Small arrows indicate wind directions; bold arrows, the Cirrus direction over Melbourne; shaded areas, the rainfall distribution during the preceding 24 hours.

(2) One of the most striking examples of the value of Cirrus observations has already been mentioned, viz., the appearance in fine weather, and, generally with a high barometer, of Cirrus coming from some Northerly point. To determine the significance of this the records have been appealed to in the same way as in the preceding case. Taking as Northerly anything between N.W. and N.N.E., there were 50 cases since August, 1899, which complied with these requirements. As the Cirrus observations were made at any time during the day and sometimes late at night, the rain records for the next two 9 a.ms. were used, but merely coastal rains were not counted. The results come out as follows:—

Rain following over New South Wales, South Australia, and Victoria	19 cases
Rain following over New South Wales and South Australia only	4 ,,
Rain following over New South Wales and Victoria only	17 ,,
Rain following over New South Wales only	7 ,,
Little or no rain	3 ,,

These results are sufficiently remarkable, showing as they do that the probability of rain falling on a considerable scale over inland New South Wales is 94 per cent., for Victoria 72 per cent., and for South Australia 46 per cent.

In judging the probabilities for Victoria the velocities with which these clouds are seen to be moving must be taken into account, as when the motion is very slow and irregular Melbourne may be taken as the extreme Southern limit of the tropical outflow, and conditions therefore likely to remain anticyclonic over Southern Victoria.

(3) A third may be given without reference to figures, as the writer has observed it so frequently.

Conditions favorable for widespread rains inland are almost invariably terminated or caused to contract Northwards if Cirrus clouds are seen to be coming from a point South of West. This is often noted in connexion with the termination of "monsoonal" depressions bringing thunderstorm rains, the general atmospheric drift from ground to Cirrus level being from a Northerly point. The first sign of the abolition of these favorable conditions, at all events over Victoria, is often given by the summits of the Cumulo-nimbus clouds beginning to lean over towards the North-east, and this may be followed by Cirrus coming from South-west.

EXAMPLES OF FORECAST VALUE OF CLOUD MOVEMENTS.

A few instances of the significance of cloud movements, chiefly Cirrus, over Melbourne may be useful.

(1) If the first Cirrus observed when a storm is approaching is from the S.S.W. or S.W. little rain may be expected.

(2) If, however, it veers rapidly Northwards as the storm approaches, and, especially if in the case of an "Antarctic" low, for any given distance of the trough the direction of movement reaches a point more Northerly than the average for that distance good general rains may be expected.

(3) If, in addition to (2), the trough is moving slowly the storm is likely to prove cyclonic round a centre passing either over Tasmania, Bass Strait, or inland Victoria. The more Northerly the track of the centre the better the rainfall, as a rule.

(4) Cirrus movements beginning well but failing to maintain their Northward backing or tending to disappear suggest either the destruction of the storm or its deflection into the far interior of the continent or possibly its slipping Southwards from the Bight. If passing North-eastward from the Bight into New South Wales or Queensland Cirro-stratus is usually visible low down in the North-western horizon and lying parallel to it.

(5) Movement persisting from some Northerly point in spite of locally fine weather is a very reliable sign of rain, especially over the interiors of New South Wales and Victoria.

(6) Cirrus tending Easterly through North indicates the storm centre to be passing Eastward North of the observer, while directions between E. and S.S.E. generally go with an active storm centre off the New South Wales South coast-line, with much rain there and in East Gippsland, and high pressure over Tasmania or South-western Victoria.

(7) Cirrus coming from South (S.S.E–S.S.W.) may have no apparent relation to storm systems, and is often seen in purely anticyclonic weather. It is also seen occasionally as the result of storm energy when the centre of a vigorous cyclone is passing over or not far South of Melbourne, or has formed somewhere off Gabo Island. But whatever its relationship, Cirrus from this direction indicates conditions very unfavorable to the development or Eastward progress of Antarctic disturbances approaching from the West.

(8) The failure of Cirrus to herald the approach of a storm is usually a sign of poor rain production over inland areas. This was very noticeable during the dry period 1895–1902 inclusive. The principal exceptions, not many, are storm systems in early stages of their development.

(9) The approach of an "Antarctic" disturbance likely to produce general rains is usually heralded by lower clouds (Fracto-cumulus, Scud, &c.) from North or N.N.E., and clouds above this level more Westerly in direction as the height increases, though rains are not usually extensive unless by the time the centre is within, say, 300 miles, Cirrus clouds are from about North-west.

(10) It sometimes happens that, as a storm previously centred inland over South Australia approaches, the clouds of middle altitudes become more Westerly instead of more Northerly in direction than the Cirrus above them. This is an indication that near the coast the control of the circulation is being transferred to higher latitudes and lessens the probability of heavy rains in Southern areas, though further inland tropical influences may still hold and good rains fall.

(11) On the other hand, it sometimes happens that in front of a promising-looking storm passing centrally over the Bight, the Cirrus clouds, after attaining a good Northerly direction, veer to near West well before the centre passes. This indicates loss of storm energy and lessening rain prospects generally, though the direction of the lower clouds may be scarcely affected.

ORIGIN OF EXTRA-TROPICAL CYCLONES.

Light is thrown upon the genesis of many cyclonic disturbances by the fact that, in Australia, at all events, they are so often preceded by this extensive air flow at Cirrus level from the tropical belt. The first air movement is undoubtedly non-cyclonic, and on a very extensive scale. A wide stream of air begins to move bodily polewards, accompanied by gradually increasing cloud, leading to thunderstorm production and widespread rains. These phenomena may be well in progress without cyclonic development until the latitude of 30° or 35° is reached, when the increasing differential effect of the earth's rotation becomes manifest in the formation of a cyclonic circulation round a central "low." The dynamic energy of this is often soon sufficient to throw a high pressure ridge across the barometric valley previously connecting it with the tropical low pressure belt, and thence on the rainfall is governed by the circulation round the low centre. The cyclone now usually proceeds on its way Eastwards as an "extra-tropical" cyclone, finally becoming merged in the great Antarctic low pressure belt.

The formation of at least some types of cyclonic circulation seems, therefore, to be merely an incident in a poleward "surge" of the atmosphere, best indicated by the movements of the upper air. The pronounced tendency for the development of an "Antarctic" from a monsoonal dip or trough logically follows, and may be regarded as a proof that this poleward "surge" has not been checked inland, but has actually reached southern waters, over which various influences conspire to give it greater vigour, such as (1) increased rate of cooling with increase of latitude; (2) greater deflective effect of the earth's rotation; (3) increased humidity, &c.

Then if we admit that cyclones originate in these more direct poleward surges of the atmosphere, especially when the field is clear for them, that is when shielded by high pressure systems to Southward from the influence of Antarctic disturbances, it also follows that similar or possibly less directly poleward flows must at least produce modifications in systems already established, although perhaps unable to give rise to new systems. This has already been to some extent demonstrated. If the Cirrus flow is from a point well North of West, then the "low" may make great increases in area and intensity, and even appear to travel Westward; if from a Southerly point then loss of energy may be expected. This is, of course, assuming that these Cirrus directions are not those directly due to the storm's own circulation. That the direction of movement of the upper air has a dominating influence upon the path as well as the life and the rain production of any storm system the observations made emphatically prove. One cannot, in fact, observe very long without discovering such simple facts as that Cirrus movements from points near West usually mean little convectional energy, that movements from the South not due to cyclonic control are destructive of it, that movements from the North favour it very strongly, &c.

The remarkable energy developed in these more direct poleward air flows, whether in summer or winter, seems to require as explanation a rate of cooling more rapid in the upper than in the lower levels of the atmosphere during the progress of the air flow into higher latitudes so as to steepen the vertical temperature gradient. The rainfall produced in these depressions is so heavy, widespread, and accompanied by so much electrical disturbance that it could hardly be due to any simple process of uniform cooling, and if the cooling were more rapid at low levels the lessening of the vertical temperature gradient would be unfavorable to ascending currents and large rain production. The reverse effect noticed when air is flowing on a large scale from the South to a great extent confirms this. Not only is this a sign of fine weather, but Cirrus wisps from South are often seen fading away, a process rarely seen with Cirrus from North.

Finally, then, it seems reasonable to conclude that one very efficient cause of weather change is to be found in atmospheric movements akin to the flow of irregular ocean currents. Such may be the latitudinal translation of masses of air to restore equilibrium temporarily lost between portions of the polar and equatorial belts. When the movement is away from the equator, clouds, rain, and at times cyclonic development will result; when in the reverse direction, fine weather.

ADDENDUM.

Since the preceding was prepared for publication, a few of the observers, scattered over the continent, have been persuaded to report the cloud movements. They have been doing this since the latter part of 1913, and the reports have not only proved most valuable aids to the daily forecast, but have thrown light upon the occurrence of many rains previously unexplainable, and written down as "non-isobaric," &c.

This is most noticeable in Western Australia, where general rains extending from the North-west coast-line Southwards to the gold-fields are invariably preceded by movements of upper clouds from points near North. In many cases these rains have fallen in spite of what seemed entirely unfavorable isobaric conditions, the rain area penetrating from the North or North-west well towards the centres of pronounced anticyclones. A feature of the latter portion of 1914 and early months of 1915 has been the frequent appearance of Cirrus moving from North or North-west over the Western Australian interior, almost invariably followed by rain there.

These favorable conditions were, however, unfortunately almost entirely limited to that State. During the earlier part of this period the South flowing upper currents were confined to the longitudes of Western Australia, and it long seemed as if the Southern limit was the 30th parallel of latitude, Cirrus movements being almost constantly from the West South of a line joining Eucla and Sydney. On the few occasions in November and December, 1914, and January, 1915, when monsoonal depressions carried rain Southwards over Victoria, Cirrus North to South movements as usual preceded them. The extraordinary persistence of the Westerly component of direction and the rarity of important departures from it is probably closely related to the terrible drought in the year 1914 which devastated the South-eastern half of the Commonwealth.

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